

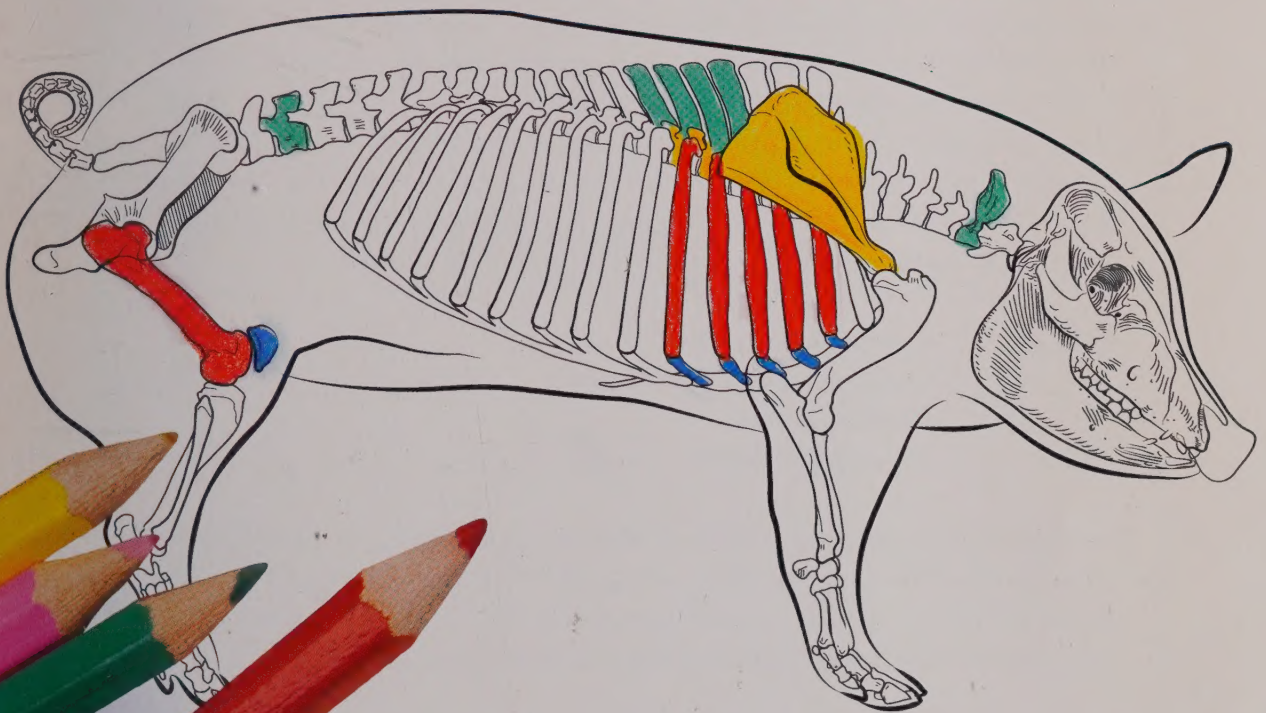
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From the Illustrator of Kaplan's Bestselling *Anatomy Coloring Book*

Fetal Pig

COLORING BOOK

A LABORATORY MANUAL



**LOGICALLY ORGANIZED FROM
EXTERNAL TO INTERNAL ANATOMY**

Clean, clear illustrations

Descriptive, instructional text

Labels for highlighting important
structural parts

Designated room for notes

STEPHANIE McCANN
JOANNE TILLOTSON



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Fetal Pig Coloring Book.

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Fetal Pig Coloring Book
A Laboratory Manual

William H. Hall, M.A., State University of New York
James H. Hall, Ph.D., Rutgers College, Newark

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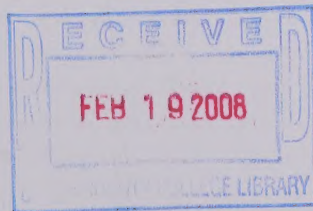
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Fetal Pig Coloring Book

A Laboratory Manual

Stephanie McCann, M.A., Santa Barbara City College
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Table of Contents

About the Authors	ix
Introduction	xi
How to Use This Book	xii
Coloring Techniques	xii
Chapter 1: Introduction	1
Terminology	1
Planes of Section	3
Chapter 2: External Anatomy	5
Sex differences	9
Histology of the skin	11
Chapter 3: Skeletal System	13
Skeleton, Lateral	15
Skull	17
Skeletal Histology	19
Chapter 4: Muscular System	21
Dissection Incisions	23
Lateral Muscles	25
Ventral Muscles	27
Dorsal Muscles	29
Lateral Forelimb	31
Medial Forelimb	33
Hind Limb	35
Medial Hind Limb	37
Dorsal Deep Shoulder and Neck Muscles	39
Muscle Histology	41
Chapter 5: Thoracic and Abdominal Viscera	43
Chapter 6: Digestive system	47
Salivary Glands	49
Oral Cavity And Pharynx	51
Sagittal Section Head and Neck, Swallowing	53
Gall Bladder and Pancreas	55
Digestive Histology	57

Chapter 7: Respiratory System	.59
Lungs, Trachea and Bronchi	.61
Bronchi and Alveoli	.63
Breathing and Histology	.65
Chapter 8: Circulatory System	.67
Arterial System	.67
Venous System	.69
Adult Circulation	.71
Fetal Circulation	.73
Vessels of Head and Neck	.75
Lateral Heart and Great Vessels	.77
Ventral Heart	.79
Dorsal Heart	.81
Frontal Plane Heart	.83
Ventral Arteries of Digestive Organs	.85
Ventral Abdominal Aorta and Caudal Vena Cava	.87
Umbilical Cord, Umbilical Vessels	.89
Portal System of Veins with Organs	.91
Circulatory Histology	.93
Chapter 9: Lymphatic System	.95
Spleen with Histology	.97
Chapter 10: Urogenital System	.99
Urogenital System, Male	.99
Urogenital System, Female	.101
Kidney	.103
Nephron	.105
Reproductive System—Male	.107
Male Histology	.109
Reproductive System—Female	.111
Female Histology	.113
Chapter 11: Nervous System	.115
Nervous System, Dorsal View	.115
Lateral Brain, Ventral Brain	.117
Dorsal Brain	.119
Sagittal Brain	.121
Eye	.123
Ear	.125
Nose	.127
Neuron	.129
Synapse	.131
Chapter 12: Endocrine system	.133
Index	.137

About the Authors

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Currently, Ms. McCann focuses on the creation of medical illustrations for use in textbooks, journals, product advertising, training manuals, and legal presentations, using both traditional and digital media. Her enjoyment of digital illustration led to 3D texture painting for computer graphics visual effects for film. Her work with Santa Barbara Studios can be seen in such films as *Star Trek: Insurrection* and *Paulie: A Parrot's Tale*. Ms. McCann specializes in work that depicts the amazing beauty of the anatomy of the human body.

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Introduction

The study of mammalian anatomy in an introductory biology course is often used to illustrate biological principles and is useful to those studying biology for many different reasons. The relevance is obvious for those planning to study anatomy further for a career in a medical field, but the study is equally useful when looking at the anatomical changes of organisms during evolution, when relating structures to physiology or biochemistry, or when examining factors relevant to conservation biology, just to name a few.

The anatomy of the pig, *Sus scrofa*, is often selected for study in introductory biology courses for two reasons. First, pig structures are similar enough to human anatomy for the study to be relevant to understanding our own biology, and to be a model organism to apply the biological principles learned in this course. Second, relatively large fetal specimens are readily available from biological supply houses who obtain them from slaughterhouses that have no use for the fetuses from pregnant sows that are being butchered. Thus, fetal pigs are relatively inexpensive, but ideally suited as dissection specimens for the study of mammalian biology.

Dissections are strongly preferred by most instructors in such a course because they provide a medium for learning that is far more effective for most students than the use of text, diagrams, or videos alone. Students—even those who are initially reluctant to participate in the activity—find that dissections contribute to learning in a variety of ways. While pictures and drawings can contribute substantially to understanding anatomy, dissection provides an additional dimension that contributes to long-term learning. Exploring and “discovering” structures for oneself help students in remembering names, appearances and locations of the anatomical structures. Students may also find that dissection facilitates understanding the whole organism—which may not be so clear from individual diagrams or pictures that one may study. Hands-on activities also contribute to both learning, motivation, and enjoyment of the activity—this coloring book provides such hands-on activities, but is substantially more effective when coupled with dissection. While most students will use this book in conjunction with dissection, it can also be used as a learning tool by students who cannot, or choose not to, dissect fetal pigs in their classes.

Like humans, the pig is a member of the phylum Chordata, subphylum Vertebrata, class Mammalia. As such, the pig has characteristic structures such as the brain and a dorsal nerve cord protected by skeletal structures called vertebrae (common to all vertebrates), or insulating hair and mammary glands to nourish the young (common to all mammals). Examples of differences between the pig (Order Artiodactyla) and human (Order Primates) include a variety of skeletal structures adapted for quadruped or biped locomotion, opposable thumbs used for grasping in humans, and enhanced emphasis in humans on the brain's cerebral cortex and associated structures which enable greater learning and communication skills. For detailed comparisons between the fetal pig and humans, we recommend using this book along with the *Anatomy Coloring Book*, by Stephanic McCann and Eric Wise, which focuses in detail on human anatomy.

HOW TO USE THIS BOOK

This coloring book has been designed to assist in learning the anatomy of the fetal pig—either being used independently to learn the anatomy, or as an adjunct to dissection. In either case, labeling the diagrams or coloring in the structure will aid in remembering these anatomical features and their relationships and understanding functions. When used with dissection, the coloring book may be used prior to working with the specimen in the laboratory, or as a review to solidify one's memory and understanding of the material.

We suggest the following procedures when using this coloring book. When first learning structures, you may look at the key at the bottom of the page, find the corresponding structure, and write in the term next to the structure before coloring the anatomical structure. This is a great technique to learn names and appearances of anatomical features. On the other hand, when using this book to review and reinforce learning, one would examine the drawings, fill in the blanks with the appropriate terms in pencil, and then check the key at the bottom of the page. Correct any mistakes and then color in the illustration in a way that cements your learning.

In most cases, the choice of colors is up to you. In a few instances, the choice of colors is designated by anatomical convention. Arteries are generally drawn in bright red, veins in deep blue, bile ducts in green, and nerves are usually yellow.

COLORING TECHNIQUES

Colored pencils usually give the best result, as they do not bleed through the page and obscure fine detail. Begin using light pressure when you color; you can always go back and deepen the color as you work on the drawings. Use the same color for the same structure when it appears in more than one drawing; use related colors for related structures—for example, using different shades of blue for different structures in the same organ system. Plan your colors before beginning each drawing, so that you can follow the anatomical conventions noted above, color related structures in similar or related colors, and continue your own color codes from one drawing to the next. Using that method will help you to easily find a structure and reinforce the relationships of its function and organ system by color as well as name and shape.

TERMINOLOGY

Before examining the anatomy of the fetal pig, you should become familiar with terminology that describes the orientation of the structures. Commonly used terms are paired to describe opposite directions.

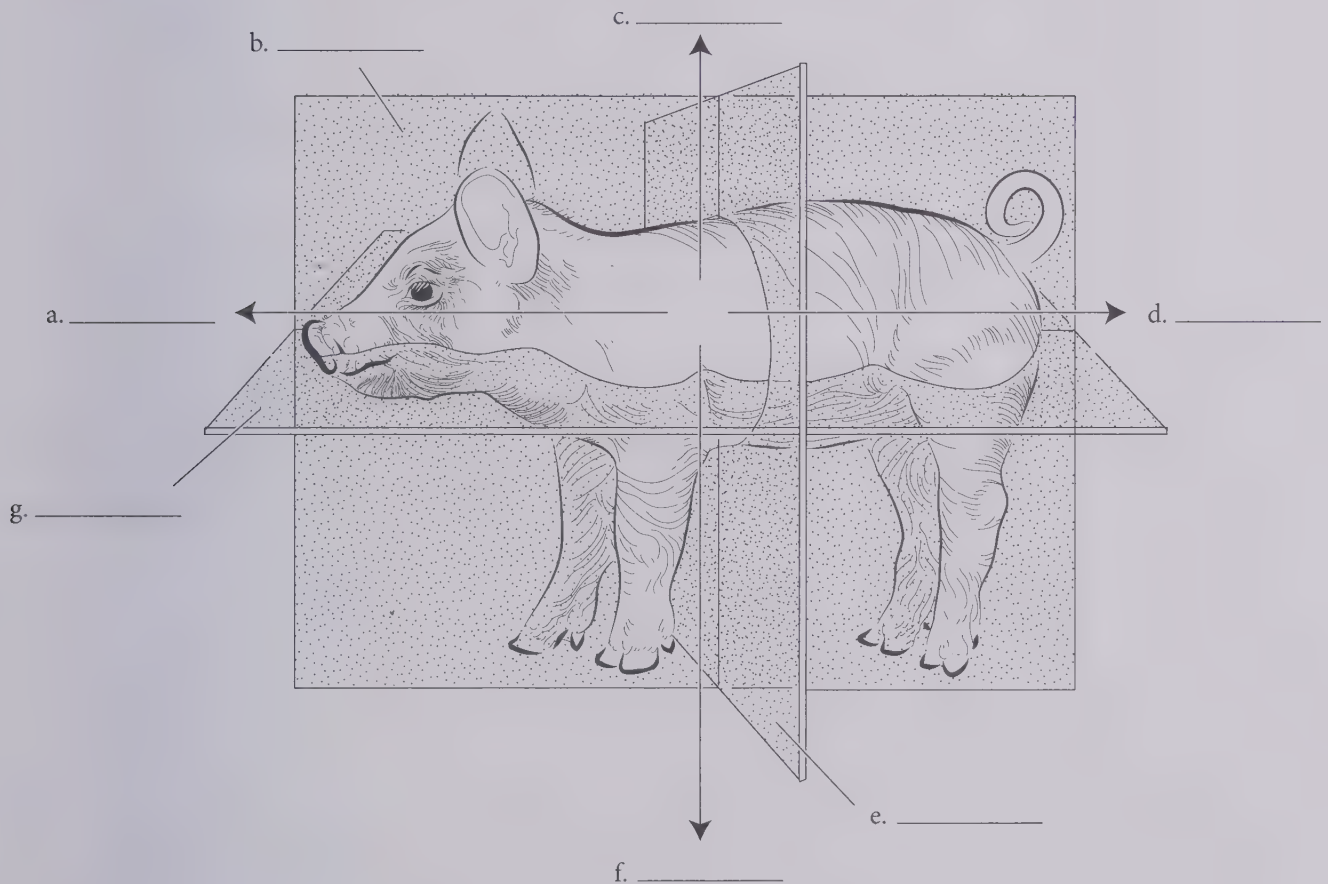
left and right	on the pig's left or right, regardless of your point of view
dorsal	toward the back
ventral	toward the belly
cranial	toward the head
caudal	toward the tail
medial	toward the center of the body
lateral	away from the center of the body
proximal	closer to the trunk, along a limb
distal	further from the trunk, along a limb
superficial	lying closer to the surface of the body
deep	lying under or below, away from the surface of the body

Two other terms—*anterior* and *posterior*—may be used differently for the pig than for the human. *Anterior* denotes the “front” of the body (in the direction of travel) or toward the head in the pig, but it is sometimes used to refer to the ventral side in bipeds like humans. *Posterior* is opposite to *anterior*, and it refers to *caudal* in the pig, but may be used to describe the dorsal side in humans.

Another helpful concept is the hierarchy of organization within the pig's body. Individual cells become specialized in many ways; groupings of similar cells with a common function are *tissues*. Several tissues of different types but working together to accomplish a function may be said to form a single *organ*. Similarly, groups of organs with a common purpose are organized into *systems* that make up the entire pig. In this coloring book, chapters each address a system of the body, and may contain drawings and descriptions of the organs, and tissue types that contribute to that system's functions.

PLANES OF SECTION

Planes of section are used in describing anatomical positions. These planes are perpendicular to one another, and provide a way to show a two-dimensional representation of a three-dimensional animal. If you were to figuratively slice completely through the pig from head to tail, cutting it into left and right portions, this would be a **sagittal** section. The midsagittal section would divide the pig into equal halves. A **frontal** or horizontal plane splits the animal into top and bottom portions, while a transverse or cross section cuts across the pig, creating front (**cranial**) and rear (**caudal**) portions.



Answer Key:

- a. Cranial (Anterior)
- b. Sagittal plane
- c. Dorsal (Superior)
- d. Caudal (Posterior)
- e. Transverse plane
- f. Ventral (Inferior)
- g. Frontal plane

You should begin your study of the pig with the external view. While most superficial structures are familiar because they are similar in all mammals, their morphology and even terminology may vary from one species to another. The external features also reveal interesting details about the fetal pig. The length of the pig from the tip of its nose to the base of the tail can be used to estimate fetal age; parturition (birth) typically occurs after 112–115 days of gestation and the average pig is 30 cm long at birth or slightly more. Much of this growth occurs during the later stages of gestation; at 56 days, the fetus is only 4 cm long.

An obvious fetal structure is the **umbilical cord**, which connected the fetus to the placenta during gestation. The **placenta** is composed of two layers—one derived from the inner lining of the sow's uterus and the other consisting of the fused chorion and allantois membranes derived from embryonic tissues. These two layers lie in close proximity to allow diffusion of nutrients, oxygen, and waste materials between the blood of the fetus and that of the mother.

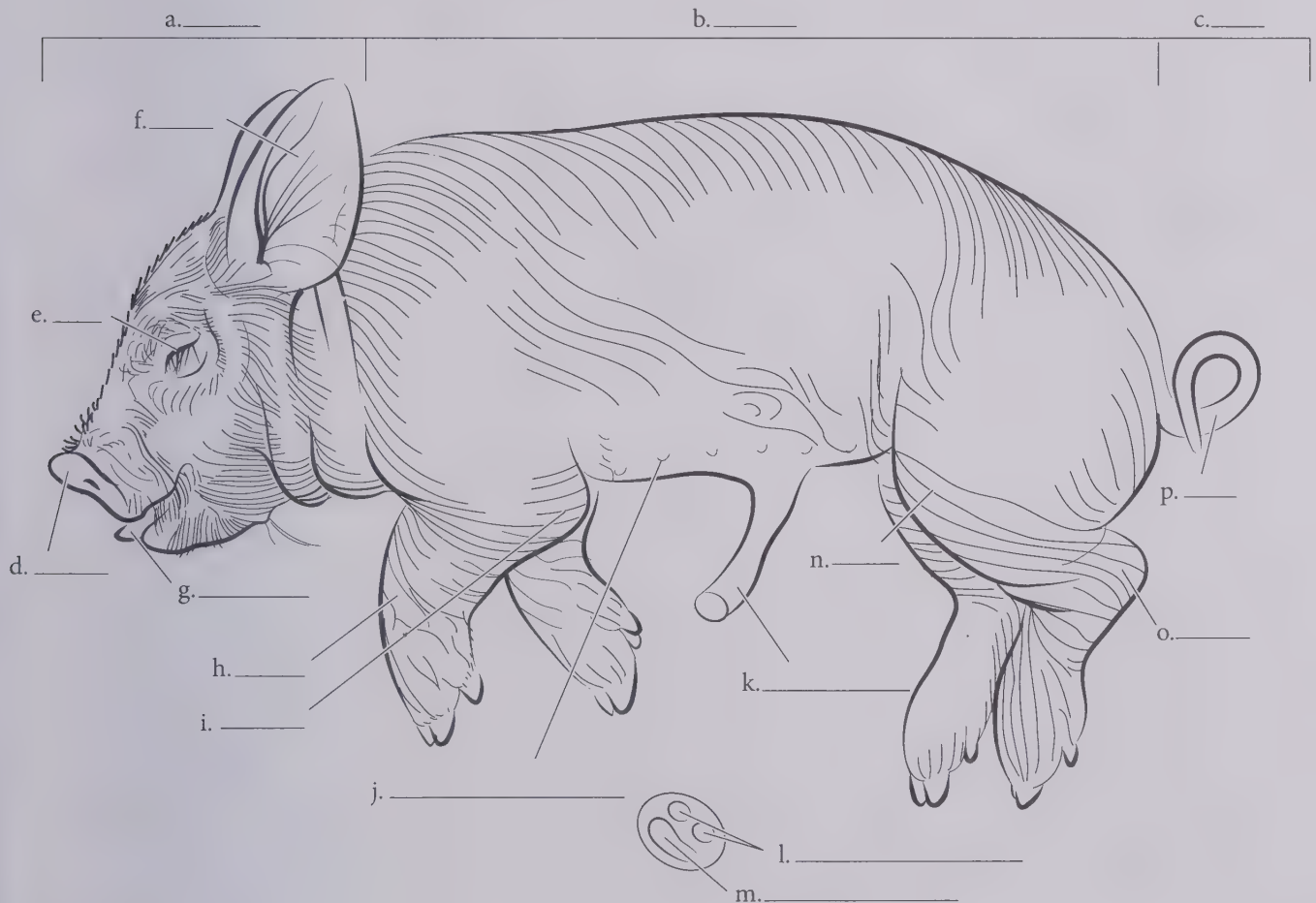
The head of the pig, as in all mammals, concentrates some important sense organs to collect information about the world around the pig. Senses of hearing, sight and smell are associated with the ears, eyes, and snout. The external ear, also known as the **auricle** or **pinna**, collects and concentrates sound for entry into the sensory portion located in the inner ear. It is also at the head where the individual will take in oxygen through the external nares in the snout, and both food and water through the mouth.

Observing the morphology of the appendages will help the student to understand locomotion of the animal. The feet are elongated and pigs walk on the tips of their toes, both adaptations that better enable them to escape predators by running away. Walking on the toes is characteristic of animals known as **ungulates**, or hoofed mammals. All ungulates have fewer than five toes; in the pig, the first toe has been lost (corresponding to the human thumb or large toe), and the second and fifth toes are greatly reduced. The pig walks primarily upon the two remaining toes (hooves) on each foot. The hooves are derived from epidermal tissues, as are the nails on human fingers and toes, or the claws on the foot of a dog or cat.

The body of the pig may be divided into three major regions—the head, trunk, and tail. Many sensory organs are concentrated in the **head**, while the **trunk** provides protection for delicate internal organs and is a site of attachment for the appendages used in locomotion. Locate the organs found in the head region and identify their functions. The external **nares** are located in the snout and form the beginning of the air passages for the respiratory system. The mouth is the site of food ingestion and contains the tongue and teeth for tasting and chewing food. The ear and eye are responsible for the senses of hearing and sight.

The appendages include two forelimbs and two hindlimbs. The **elbow** and **knee** of the pig are located close to the trunk, and the **wrist** and **ankle** are raised off the ground because the pig literally walks on its toes. Locate these joints in the diagram.

A cross section of the umbilical cord shows that it contains three blood vessels—two **umbilical arteries** that carry deoxygenated and waste-laden blood into the placenta from the fetus, and a single large **umbilical vein** that carries oxygenated and nutritionally enriched blood from the placenta toward the fetal heart.

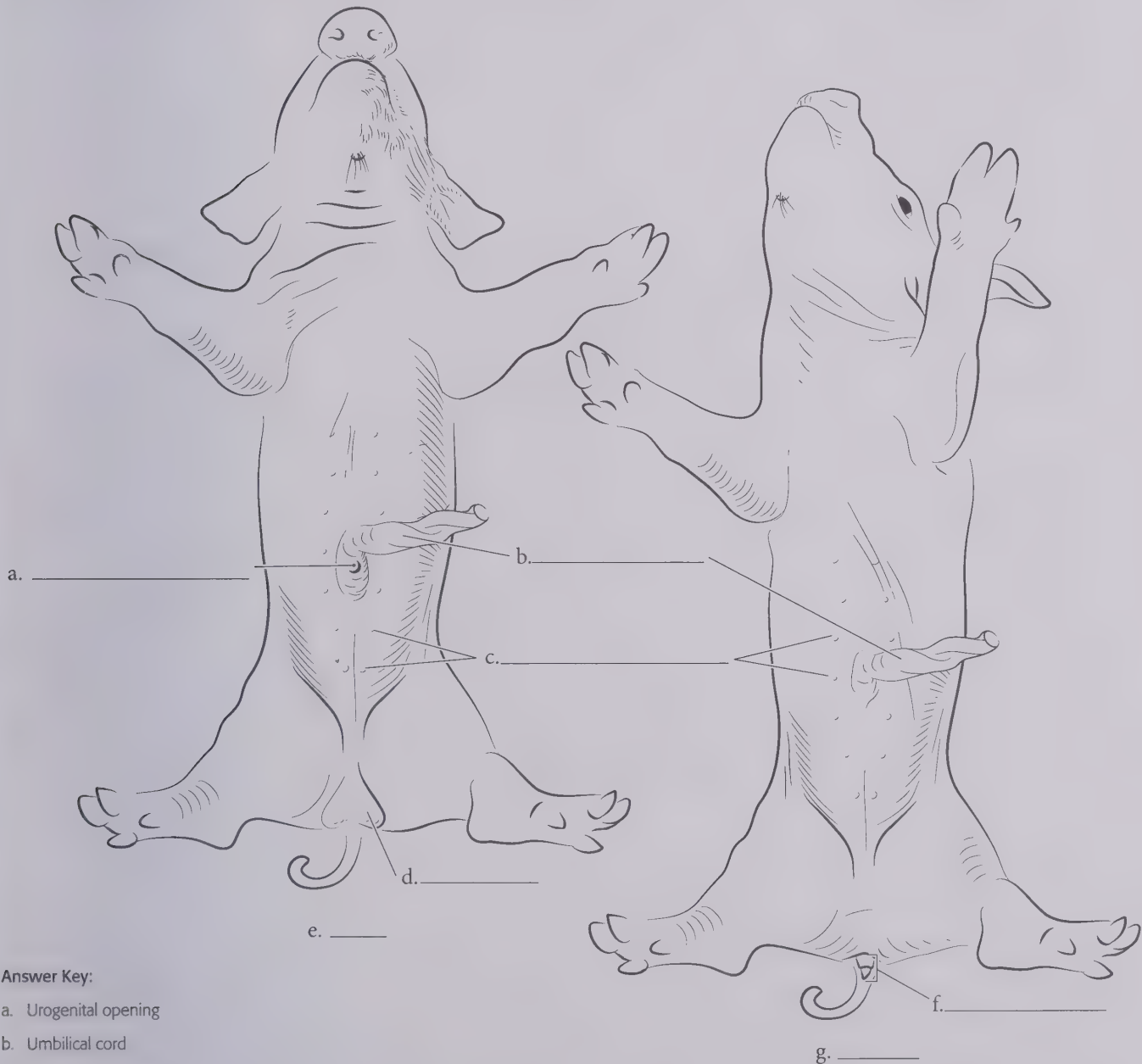
**Answer Key:**

- | | |
|----------------------------------|-----------------------|
| a. Head | i. Elbow |
| b. Trunk | j. Mammary papilla |
| c. Tail | k. Umbilical cord |
| d. Snout | l. Umbilical arteries |
| e. Eye | m. Umbilical vein |
| f. External ear (auricle, pinna) | n. Knee |
| g. Tongue | o. Ankle |
| h. Wrist | p. Tail |

SEX DIFFERENCES

You can tell the sex of a fetal pig by observing several structures on the ventral surface. Both males and females have 5–7 pairs of teats, or **mammary papillae**, along the ventral surface of the trunk, but they will become functional mammary glands only in the adult female. In males, a urogenital opening is found on the abdomen, just caudal to the umbilical cord, and is the opening for the penis. The male's **scrotum** is a

sac of skin beneath the anus and between the hind legs. The testes will descend into the scrotum from the abdominal location where they develop, and this usually occurs before the pig is born, so the scrotum may contain the testes in larger fetal pigs. The urogenital opening of females is found on a spike-like **urogenital papilla** located ventral to the anus and tail.



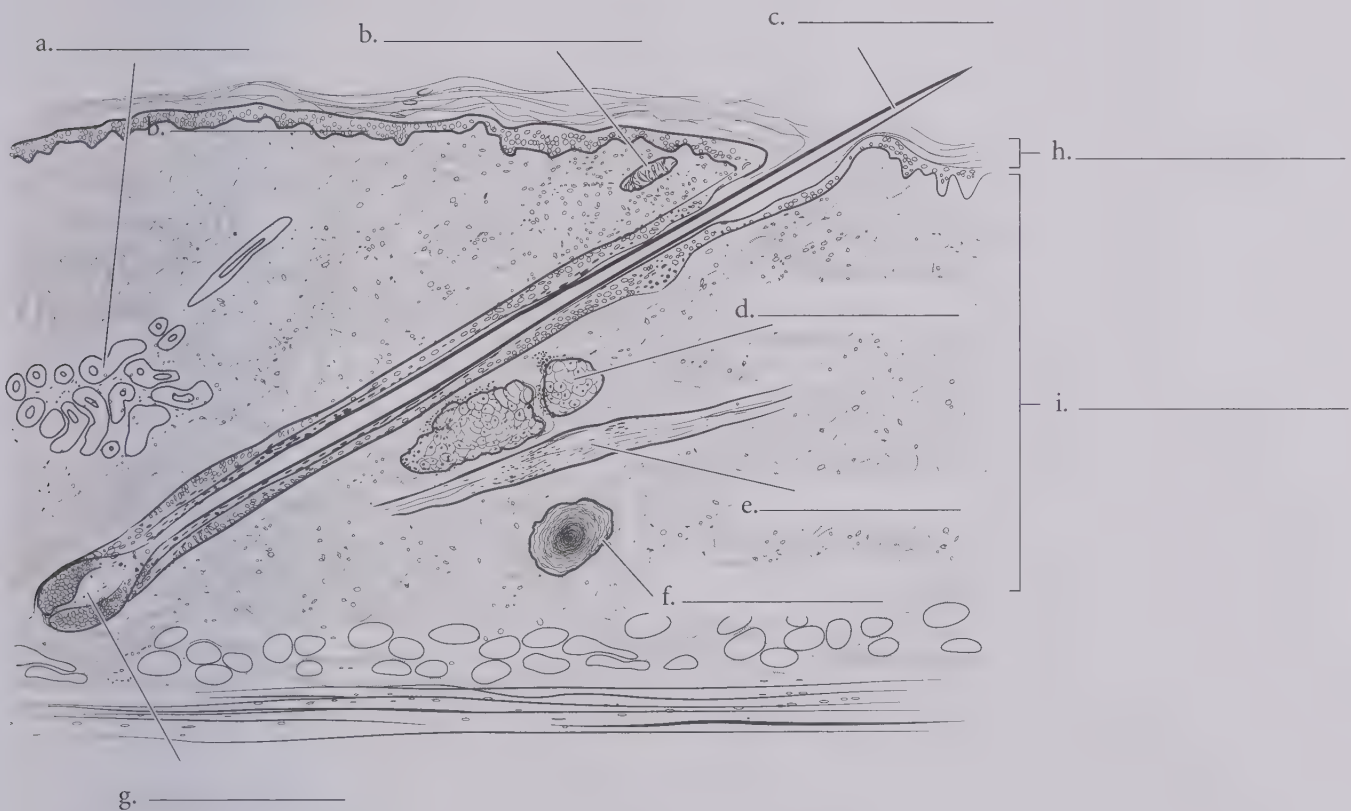
Answer Key:

- a. Urogenital opening
- b. Umbilical cord
- c. Mammary papillae
- d. Scrotal sac
- e. Male
- f. Urogenital papilla
- g. Female

HISTOLOGY OF THE SKIN

The integumentary system consists of the **skin** which is the largest organ of the body. Its function is twofold, protecting the body from external damage by physical assault or ultraviolet light, and helping to maintain a stable internal environment within the body by preventing water loss and regulating loss of heat; it also is a location for many types of sensory receptors. The outer layer is the **epidermis**, with the surface containing many flattened, dead cells. The deeper layer of the skin is the **dermis**, containing a diverse array of sensors, blood vessels, secreting organs, and hair follicles. Subcutaneous tissue below the dermis consists of fat and connective tissue, with many larger blood vessels and nerves; its function

is crucial to temperature regulation. Unique to mammals, **hair** originates within the dermis in **follicles** and functions largely in temperature regulation and sensing touch. Sebaceous (oil) glands may be found adjacent to hairs. Erector muscles attached to the hair follicle function to lift the hair to an erect position—creating a better insulating layer than when the hairs lie flat. Sweat glands, on the other hand, secrete water to evaporate and carry heat away from the body. Sensory structures in the dermis include mechanoreceptors such as **Meissner corpuscles** that are touch receptors and the deeper **Pacinian corpuscles** that detect pressure.



Answer Key:

- a. Sweat gland
- b. Meissner corpuscle
- c. Hair
- d. Sebaceous gland
- e. Arrector pili muscle
- f. Pacinian corpuscle
- g. Hair follicle
- h. Epidermis
- i. Dermis

The vertebrate skeleton is composed of bones that not only protect delicate internal organs, but provide structure for the body and an attachment site for muscles used in locomotion. Bones serve as a reservoir for calcium and other minerals, and may contain marrow where blood cells are formed. The skeletons of all mammals are essentially the same, although individual bones may be different in shape or strength because of the organism's mode of locomotion. The principal differences between the pig and human, for example, arise as a result of the quadruped locomotion of the pig versus the bipedal form of the human.

In the fetal pig, the bones of the skeleton develop as cartilage, which is later replaced by the harder bone tissue of the adult. The adult skeleton contains cartilage in addition to bone; it provides functions including support, calcium storage, and cushioning between bones at joints such as those where long bones come together. Preserved skeletons of humans or other adult animals contain only the bone tissues, but since fetal skeletons consist of cartilage, students rarely study skeletons of fetal pigs and examine human or cat adult skeletons. In this coloring book, however, you will see the shape and relationships of the bones as they are found in the pig.

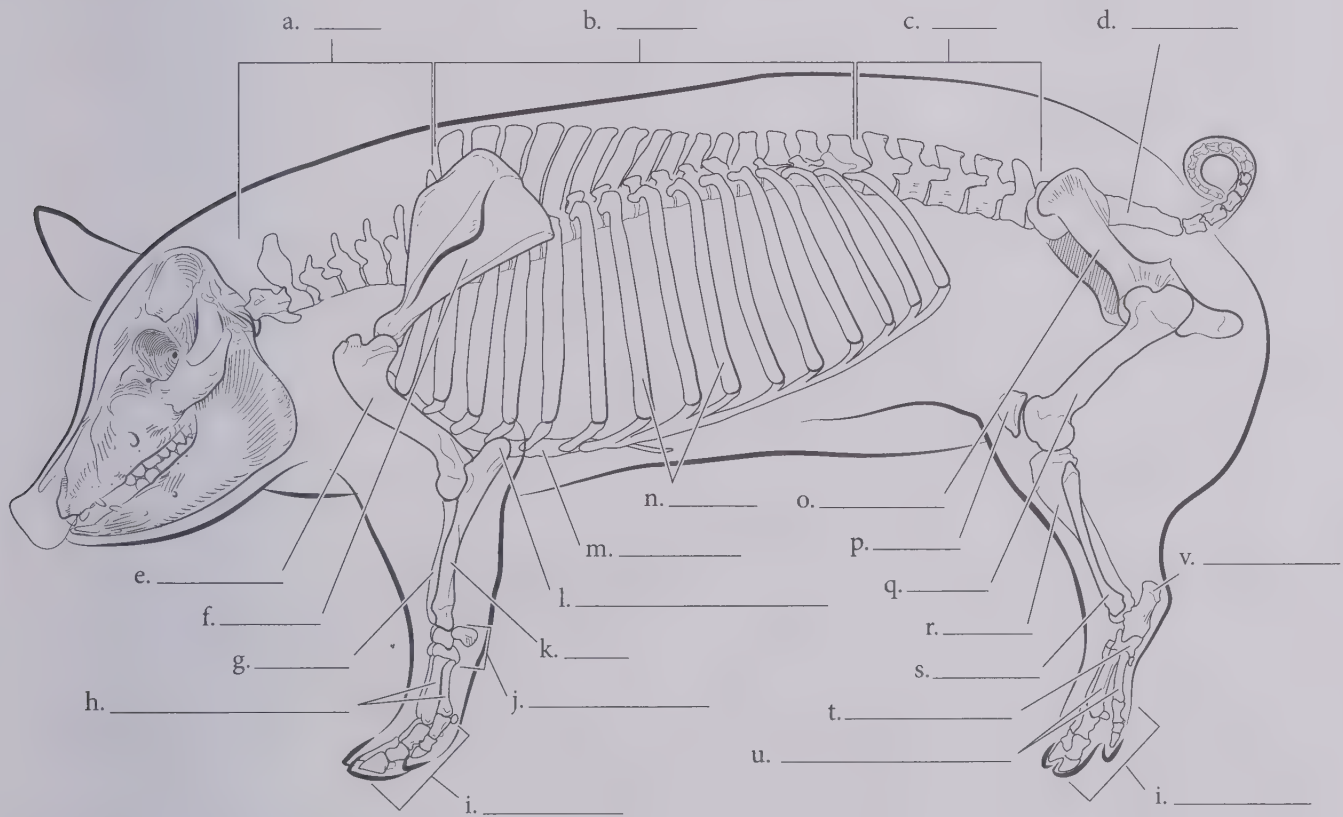
The skeleton is divided into two major divisions—the **appendicular skeleton** including the bones of the appendages and their supporting **pelvic** and **pectoral girdles**, and the **axial skeleton** consisting of the **skull** and **vertebrae**. Use different colors for the two skeletal divisions to help you remember their names and locations.

Bones articulate with one another at joints, allowing for varying degrees and ranges of movement. Where bones meet one another, try to understand the range of motion of the joint, as it will help you to remember the names and locations together.

SKELETON, LATERAL

The vertebrae are part of the axial skeleton and can be divided into five regions. The **cervical** or neck region has seven, including the cranial two vertebrae which have special names—the atlas and axis; the **thoracic** or chest region may have anywhere from 13–17; the **lumbar** or abdominal region has five; the **sacrum** in the adult pig is composed of four vertebrae fused together and articulates with the bones of the pelvis; and the remaining caudal vertebrae are located in the tail. Each vertebra has a central canal for the passage of the spinal cord, with varying bony processes extending dorsally or laterally to provide attachment for muscles or articulation with other vertebrae or ribs. Thoracic vertebrae provide the attachment point for the **ribs**, some of which are connected by cartilage with the **sternum** or breastbone (true ribs), while others have cartilage that connects to an adjoining rib (false ribs).

The pectoral girdle supports the forelimbs and includes the **scapula** or shoulder blade; unlike humans, there is no clavicle in the pig. The pelvic girdle supports the hindlimbs and includes several bones which fuse to form the coxal bone in the pig, called the **os coxae**. The bones of the legs are analogous in most mammals, including the pig and humans. Find and color the forelimb bones—**humerus**, **ulna**, and **radius**, along with the wrist bones, the **carpals**, and the forefoot bones, the **metacarpals** and **phalanges**. Find and color the bones of the rear leg—**femur**, **tibia** and **fibula**, as well as the ankle bones, the **tarsals**, and the foot bones, the **metatarsals** and phalanges.

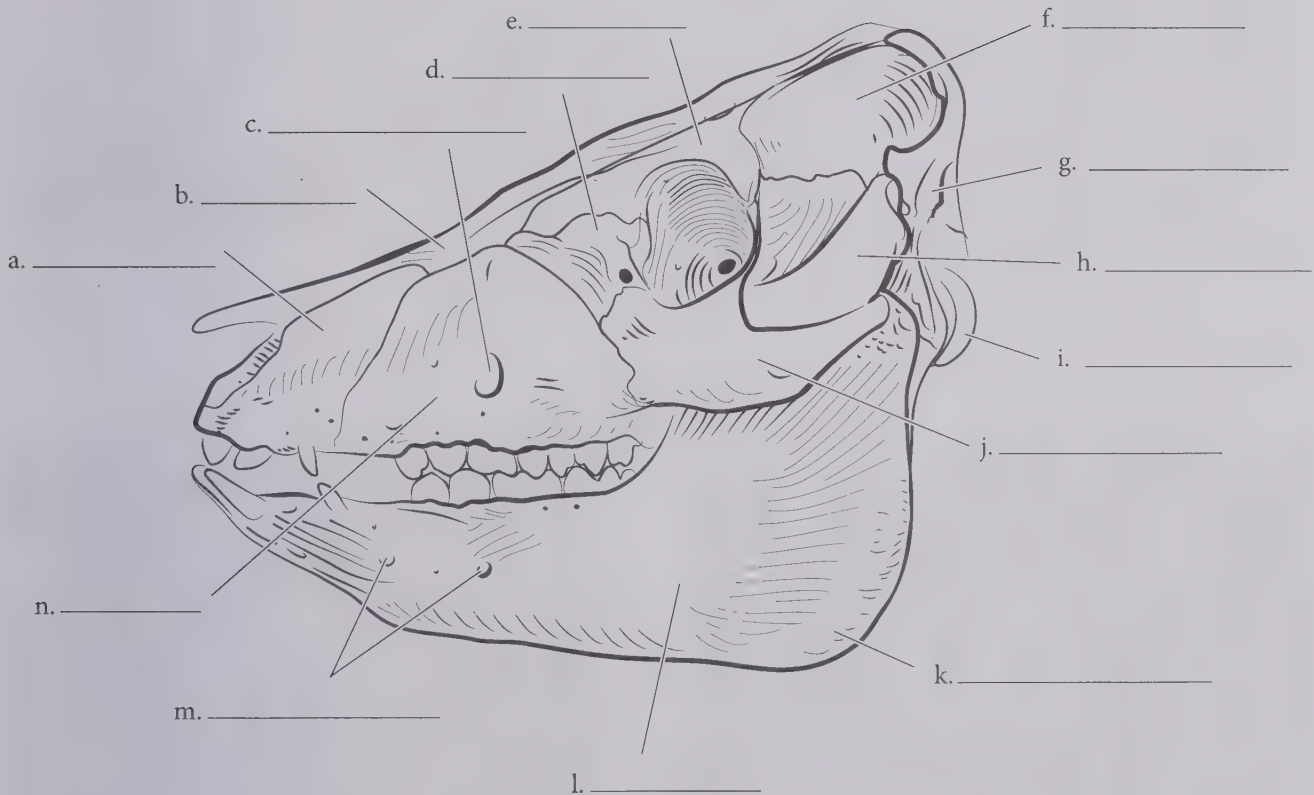


Answer Key:

- | | | |
|---------------------------------------|------------------------------------|---------------------|
| a. C1–7 | h. Metacarpal bones | p. Patella |
| b. T1–T15
(variable from 13 to 17) | i. Phalanges | q. Femur |
| c. L1–5 | j. Carpal bones | r. Tibia |
| d. Sacrum | k. Ulna | s. Fibula |
| e. Humerus | l. Olecranon | t. Tarsal bones |
| f. Scapula | m. Sternum | u. Metatarsal bones |
| g. Radius | n. Ribs | v. Calcaneus |
| | o. Hip bone (Coxal bone, Os coxae) | |

SKULL

The skull is composed of a number of bones that are fused to form a **cranium** that surrounds and protects the brain and sense organs; other portions of the cranium articulate with the **mandible** and surround portions of the digestive and respiratory systems. The names of the bones are often associated with the underlying structures; i.e., the **frontal**, **parietal**, **occipital**, and **temporal** bones are roughly located near brain lobes of the same name. The **incisive bone** has sockets for the upper incisor teeth, while the adjoining maxilla has sockets for the upper canine, premolar, and molar teeth. Making such associations will aid in remembering their names! The eye socket is formed by the frontal, **lacrimal**, **zygomatic**, and temporal bones, while the external acoustic meatus, or external ear, is surrounded by the temporal bone. **Foramina** are located in several of the bones; they are holes that allow the passage of blood vessels and nerves.



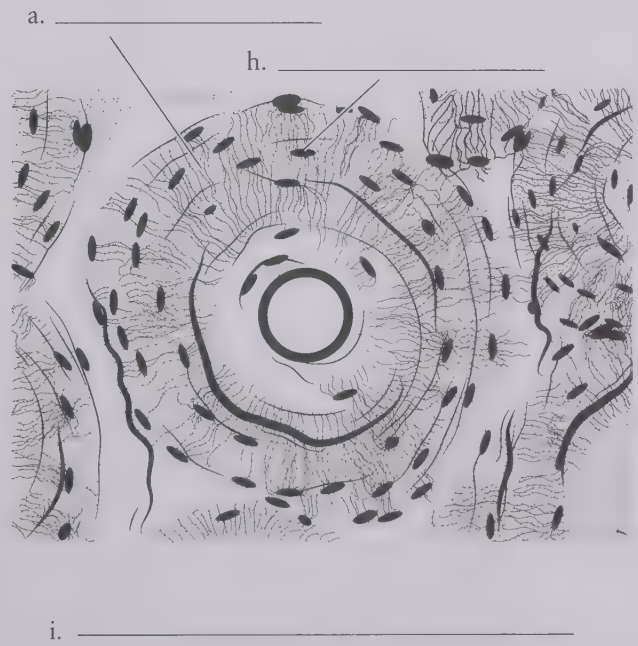
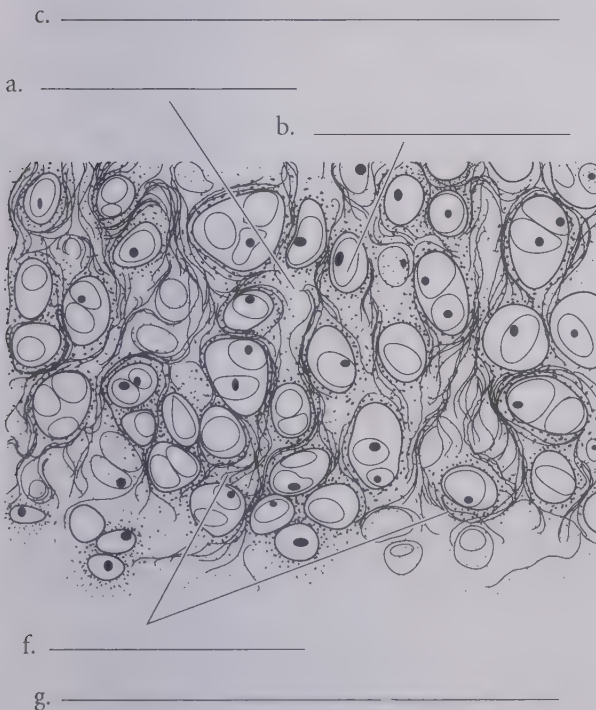
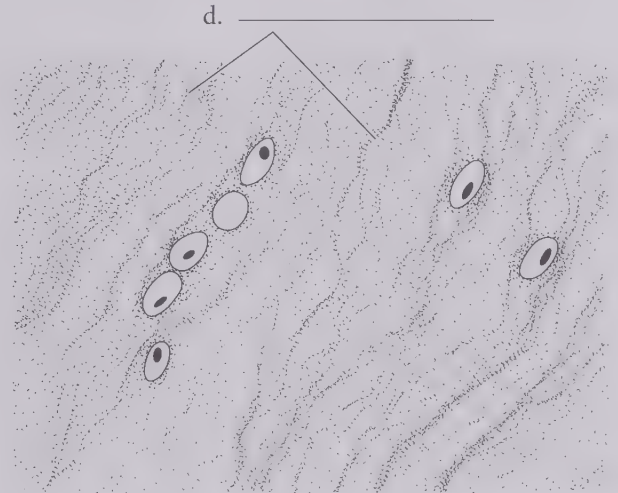
Answer Key:

- | | |
|-------------------------|----------------------|
| a. Incisive bone | h. Temporal bone |
| b. Nasal bone | i. Occipital condyle |
| c. Infraorbital foramen | j. Zygomatic bone |
| d. Lacrimal bone | k. Angle of mandible |
| e. Frontal bone | l. Mandible |
| f. Parietal bone | m. Mental foramina |
| g. Occipital bone | n. Maxilla |

SKELETAL HISTOLOGY

Bone and cartilage are fundamental connective tissues of the skeleton. These tissues consist of a nonliving matrix plus the living cells (**osteocytes** or **chondrocytes**) that secrete the matrix. In the fetal pig, most skeletal structures are composed of cartilage which is later replaced by bone in many. Several kinds of cartilage are characterized by the matrix proteins. **Elastic cartilage** contains elastin fibers and provides the flexibility needed by cartilage in the epiglottis, as well as locations such as the nose and ear. **Hyaline cartilage** has a relatively clear matrix with a

network of collagen fibers and persists in the adult as rings that hold open the trachea for the passage of air, for example. **Fibrous cartilage** is more dense in collagen fibers than hyaline and may be found in the intervertebral discs. **Bone** consists of a dense matrix containing calcium salts; its osteocytes are organized into units and are concentrically arranged around a central Haversian canal where blood vessels pass to carry nutrients to the osteocytes.



Answer Key:

- | | | |
|----------------------|-----------------------|----------------------|
| a. Matrix | d. Collagenous fibers | g. Elastic cartilage |
| b. Chondrocytes | e. Fibrocartilage | h. Osteocyte |
| c. Hyaline cartilage | f. Elastic fibers | i. Bone |

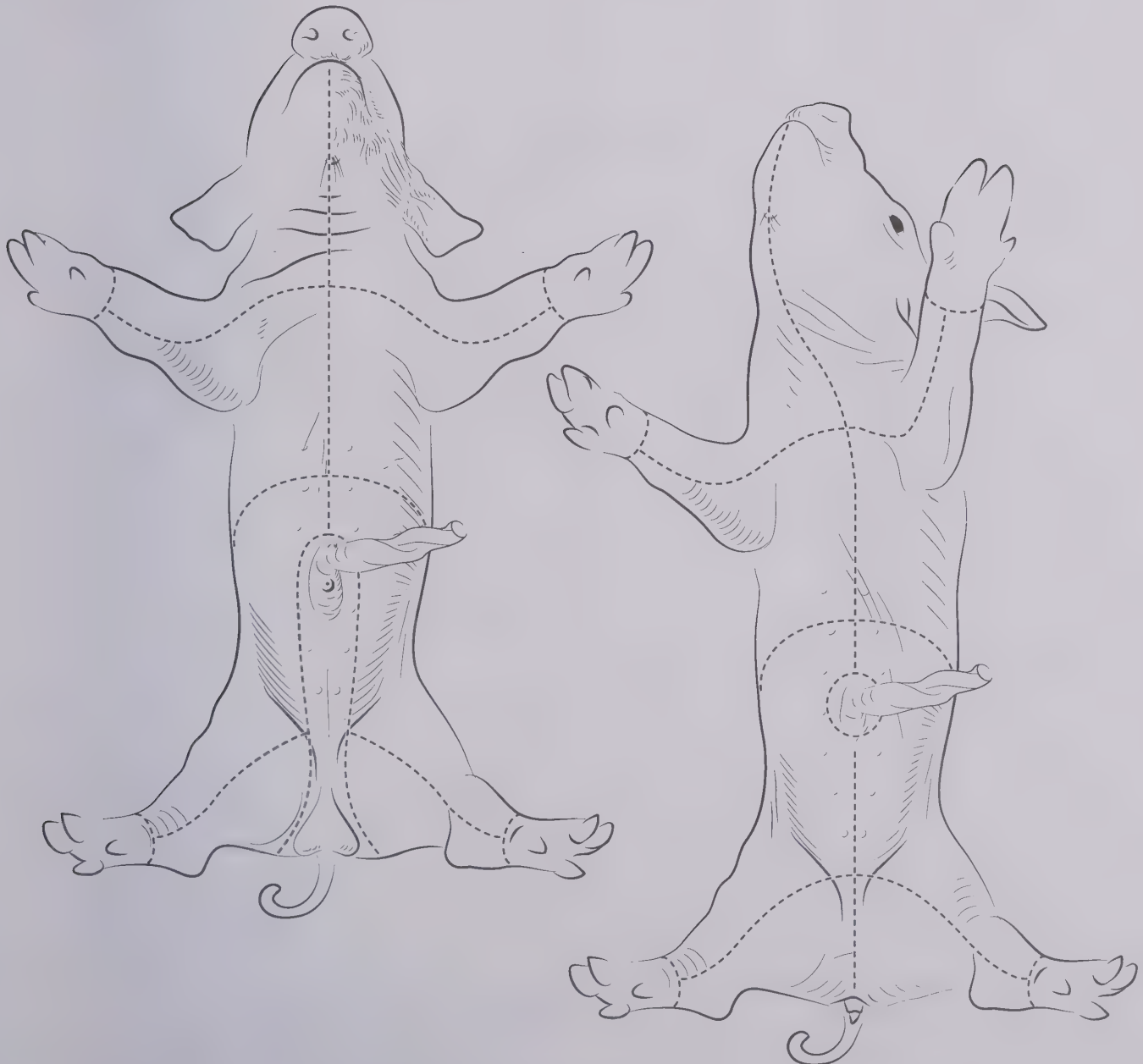
Muscles are bundles of cells capable of contraction. **Somatic** or voluntary muscles function along with the skeleton for locomotion or moving one body part in relation to another, while **visceral** or smooth muscles are found in organs such as the digestive tract where food is moved along by contraction of smooth muscles; a third type is cardiac muscle which pump bloods through the body.

In almost every case, the fetal pig has the same somatic muscles as humans, although there are some variations in size or location due largely to the quadruped/biped differences. Each muscle has a characteristic location—attaching to skeletal elements by connective tissue called tendons. Each muscle originates or attaches to a bone (its **origin**) which remains in a fixed position when the muscle contracts. The other end of the muscle inserts on or attaches to a bone (its **insertion**) which is usually free to move. Also, each muscle performs a characteristic function or **action**, such as: **adductors** move a body part toward the midline, while **abductors** draw a body part away from the midline of the body; **protractors** move a limb forward while **retractors** move that limb backwards; **flexors** move a limb or body part against another body part, while **extensors** straighten a limb or body part; and **constrictors** contract or shorten a body part. Note that many of the actions are paired with an opposite activity in another muscle. Since muscles can only contract or shorten, they cannot push a body part back after moving it in one direction. A second muscle must return the body part to its original position after the first muscle relaxes.

You should develop a strategy for coloring muscles: For example, select a pair of related colors (such light and dark blues) to represent all adductors and their correlated abductors, or another pair for all flexors and extensors. This will aid your memory of the function for each muscle.

DISSECTION INCISIONS

Most somatic muscles lie between the skin and the internal organs or bones and must be exposed in order to study them. The diagrams in this chapter have been drawn with the skin removed. After cutting carefully through the skin along the dotted lines shown here for both male and female pigs, the skin has been gently separated from the deeper layers without damaging underlying muscles and organs, preserving those tissues and organs for detailed study.



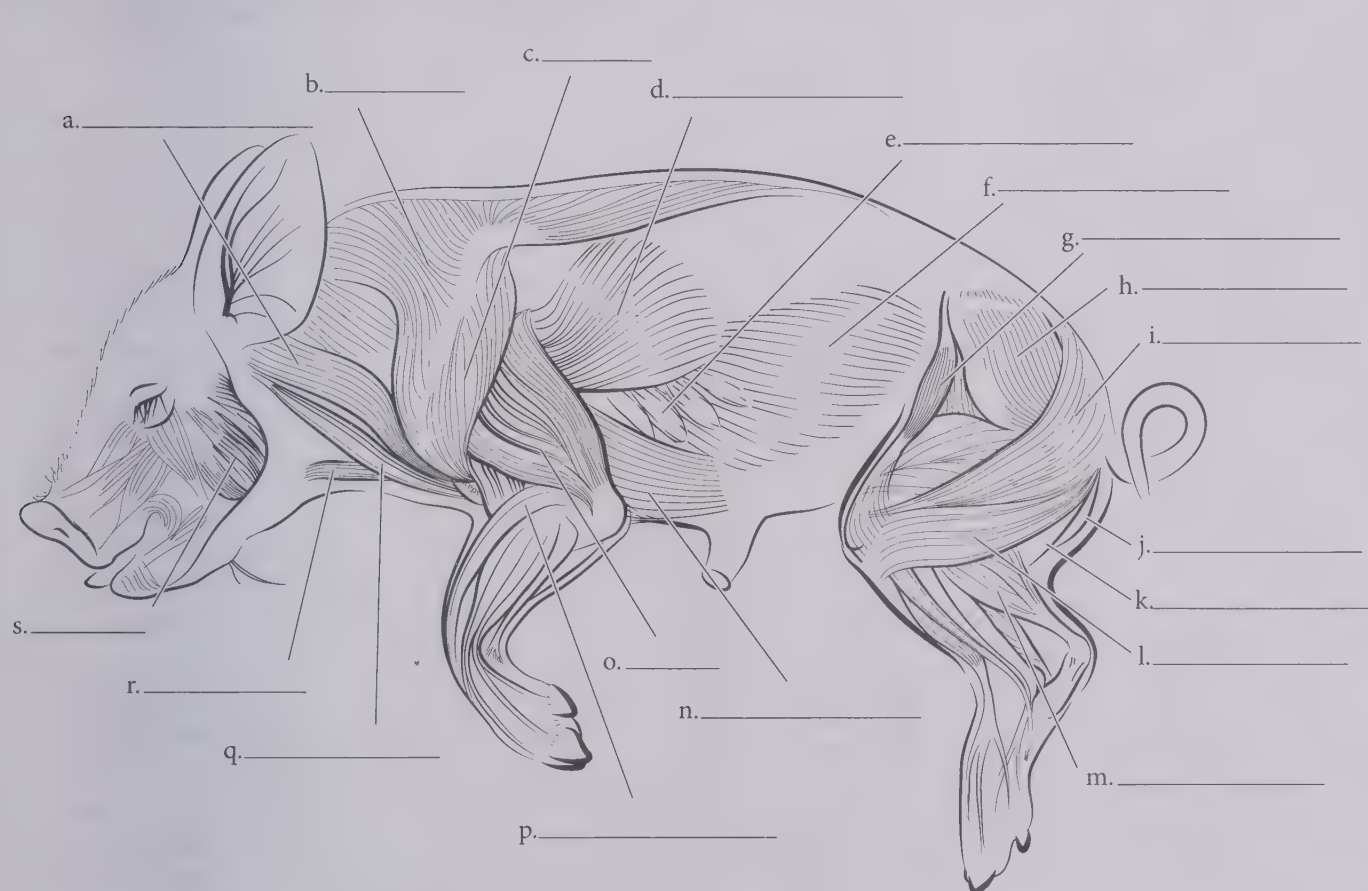
LATERAL MUSCLES

The **masseter** is a large muscle that controls the closing of the jaw; it originates on the zygomatic arch region of the skull and inserts on the coronoid process of the mandible.

In the shoulder region, the **trapezius** is a grouping of thin, broad muscles that originate on the vertebrae of the neck and thorax and insert on the scapula; they function in moving the shoulder forward or backwards. The fan-shaped **serratus anterior** originates on several ribs and vertebrae; it inserts on the dorsal portion of the scapula, helping to move it forward and back. The **brachiocephalic**, **deltoid**, and **latissimus dorsi** all insert on the humerus and function to move the forelimb. Since the pectoral girdle does not actually articulate with the vertebral column, several muscles including the serratus anterior act like a sling to transfer some of the weight of the trunk to the scapula and forelimb.

In the abdominal region, large sheetlike muscles such as the **external oblique** are part of the body wall that completely surrounds the internal organs.

In the pelvic region, several major muscles connect across both the hip and knee joints, controlling both the thigh and lower leg simultaneously. The **tensor fasciae latae** both extends the lower leg and protracts the thigh. The **biceps femoris**, **semitendinosus**, and **gluteus superficialis** act to flex the lower leg and retract the thigh. The gluteus medius both retracts and abducts the thigh. The **semimembranosus** acts to retract the thigh.



Answer Key:

- | | |
|--|---|
| a. Brachiocephalic (Brachiocephalicus) | k. Semitendinosus |
| b. Trapezius | l. Biceps femoris |
| c. Deltoid | m. Gastrocnemius |
| d. Latissimus dorsi | n. Pectoralis minor
(Pectoralis ascendens, Pectoralis profundus) |
| e. Serratus anterior (Serratus ventralis) | o. Triceps |
| f. External oblique | p. Extensor carpi radialis
(Extensor carpi brachialis) |
| g. Tensor fasciae latae | q. Sternomastoid |
| h. Gluteus medius | r. Sternohyoid |
| i. Gluteus superficialis (Gluteus maximus) | s. Masseter |
| j. Semimembranosus | |

VENTRAL MUSCLES

In the neck region, a group of muscles along the midline originate on the sternum and assist in swallowing. The **sternohyoid** inserts on the small hyoid bones, and the deeper **sternothyroid** (not shown) inserts on the thyroid cartilage. The **sternomastoid** originates on the cranial end of the sternum and inserts on the mastoid process at the rear of the skull to enable turning and depressing the head. The **platysma** is a large sheet-like muscle of the skin that is not attached to bone, but to the fascia—a fibrous connective tissue found between the shoulder muscles and the skin. Such muscles allow the pig to “twitch” regions of its skin without moving the underlying bones.

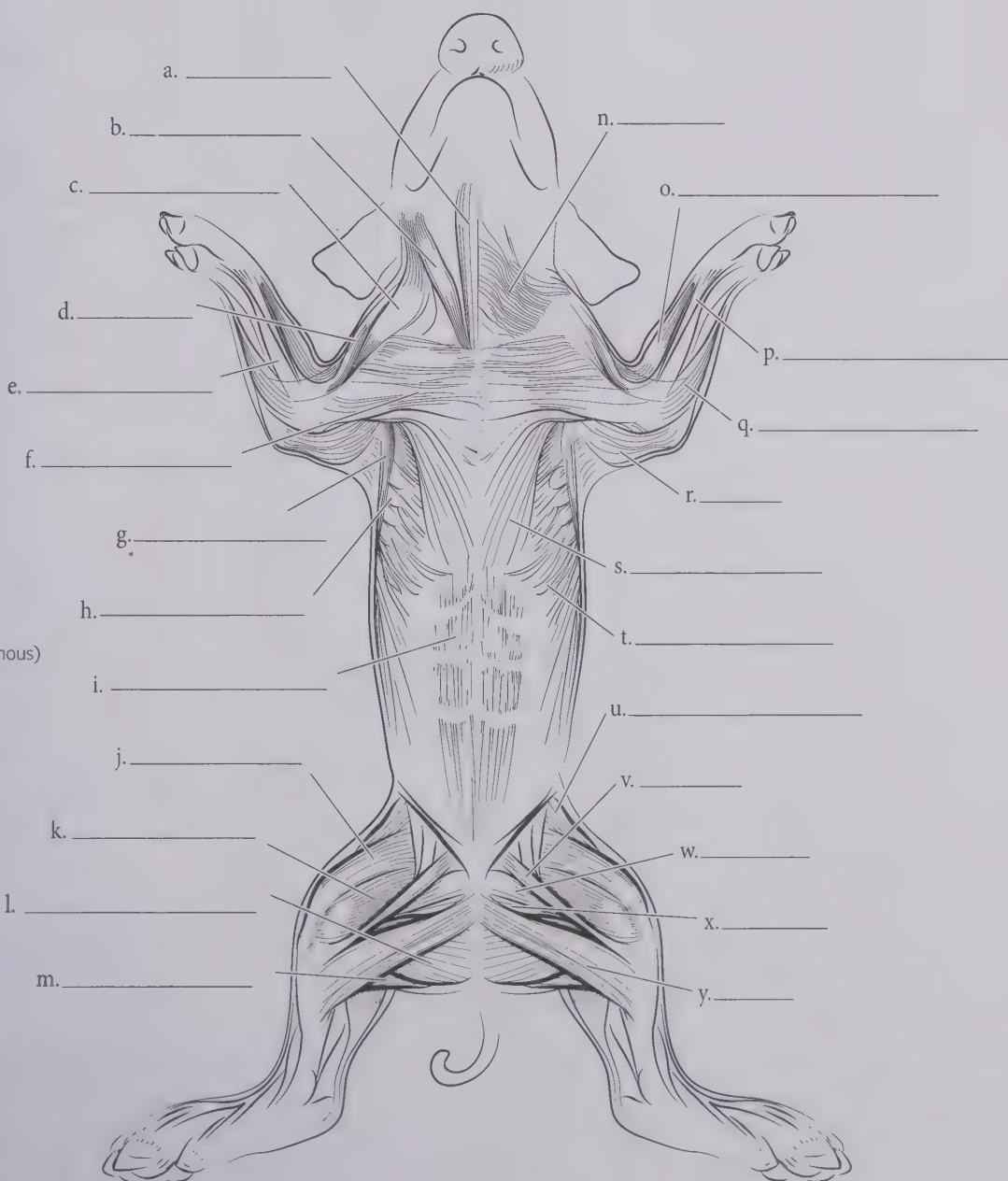
On the ventral side of the chest, the **pectoralis superficialis** originates on the sternum and inserts on the humerus, functioning in adducting and retracting the forelimb. The brachiocephalic muscle helps to adduct the forelimb while the **brachialis** flexes the lower forelimb. Other forelimb muscles such as the **palmaris longus** control wrist flexion and other movements of the wrist.

Along the trunk, a group of thin, sheet-like muscles of the body wall function to support the abdominal wall and assist in breathing. The external oblique and the deeper **internal oblique** and transversus abdominis (not shown) originate on ribs and fascia and insert at the ventral side on a connective tissue structure known as the linea alba. Serving a similar function is the **rectus abdominis** which extends linearly along the ventral midline.

In the pelvic region, several large muscles originate on parts of the pelvis and move the hind legs. Inserting on the tibia; the **gracilis** adducts and retracts the thigh and flexes the lower leg, while the **sartorius** adducts the thigh and extends the lower leg. The **adductor** muscle inserts along the length of the femur where it not only adducts but also retracts the thigh. The small **pectineus** also inserts on the femur and adducts the thigh.

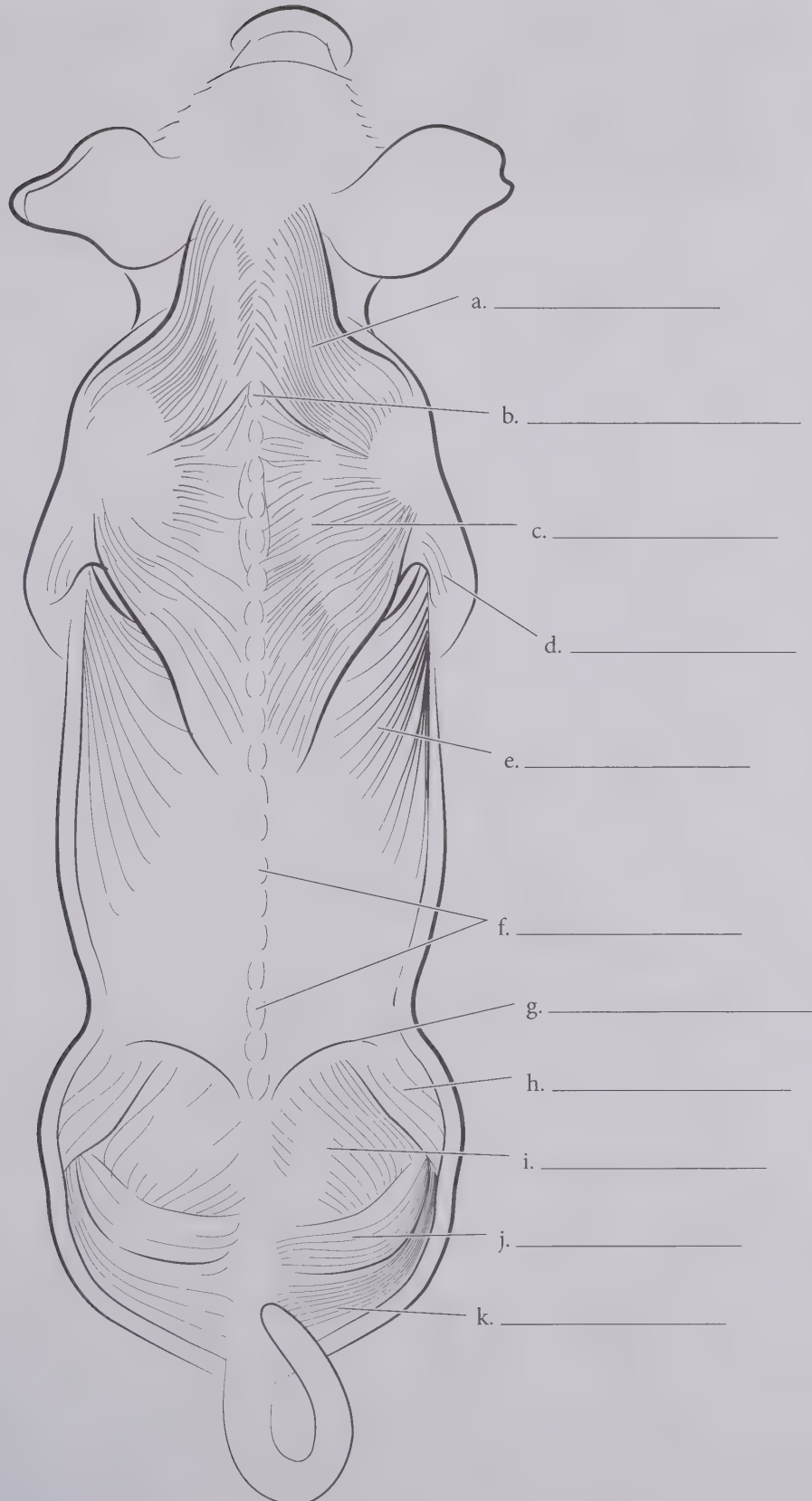
Answer Key:

- a. Sternohyoid
- b. Sternomastoid
- c. Brachiocephalic (Brachiocephalicus)
- d. Brachialis
- e. Palmaris longus
- f. Pectoralis major (Pectoralis transversus, Pectoralis superficialis)
- g. Latissimus dorsi
- h. Serratus anterior (Serratus ventralis)
- i. Rectus abdominis
- j. Rectus femoris
- k. Vastus medialis
- l. Semimembranosus (Semimembranosus)
- m. Semitendinosus (Semitendinosus)
- n. Platysma
- o. Extensor carpi radialis (Extensor carpi brachialis)
- p. Flexor carpi radialis
- q. Flexor carpi ulnaris
- r. Triceps
- s. Pectoralis minor (Pectoralis ascendens, Pectoralis profundus)
- t. External oblique
- u. Tensor fasciae latae
- v. Sartorius
- w. Pectineus
- x. Adductor
- y. Gracilis



DORSAL MUSCLES

The superficial back and neck muscles of the pectoral region include the **acromiotrapezius** muscles that originate on the spinous processes of the cervical and first thoracic vertebrae and insert on the scapula to move it forward and toward the middorsal line; the **spinotrapezius** also originates on the spines of thoracic vertebrae, inserts on the scapula, and functions to move it dorsally and posteriorly. In humans, the trapezius is a single muscle but its origins and insertions are similar to the group of trapezius muscles of the pig. Other muscles shown here serve to move the forelimb and the hind limb.



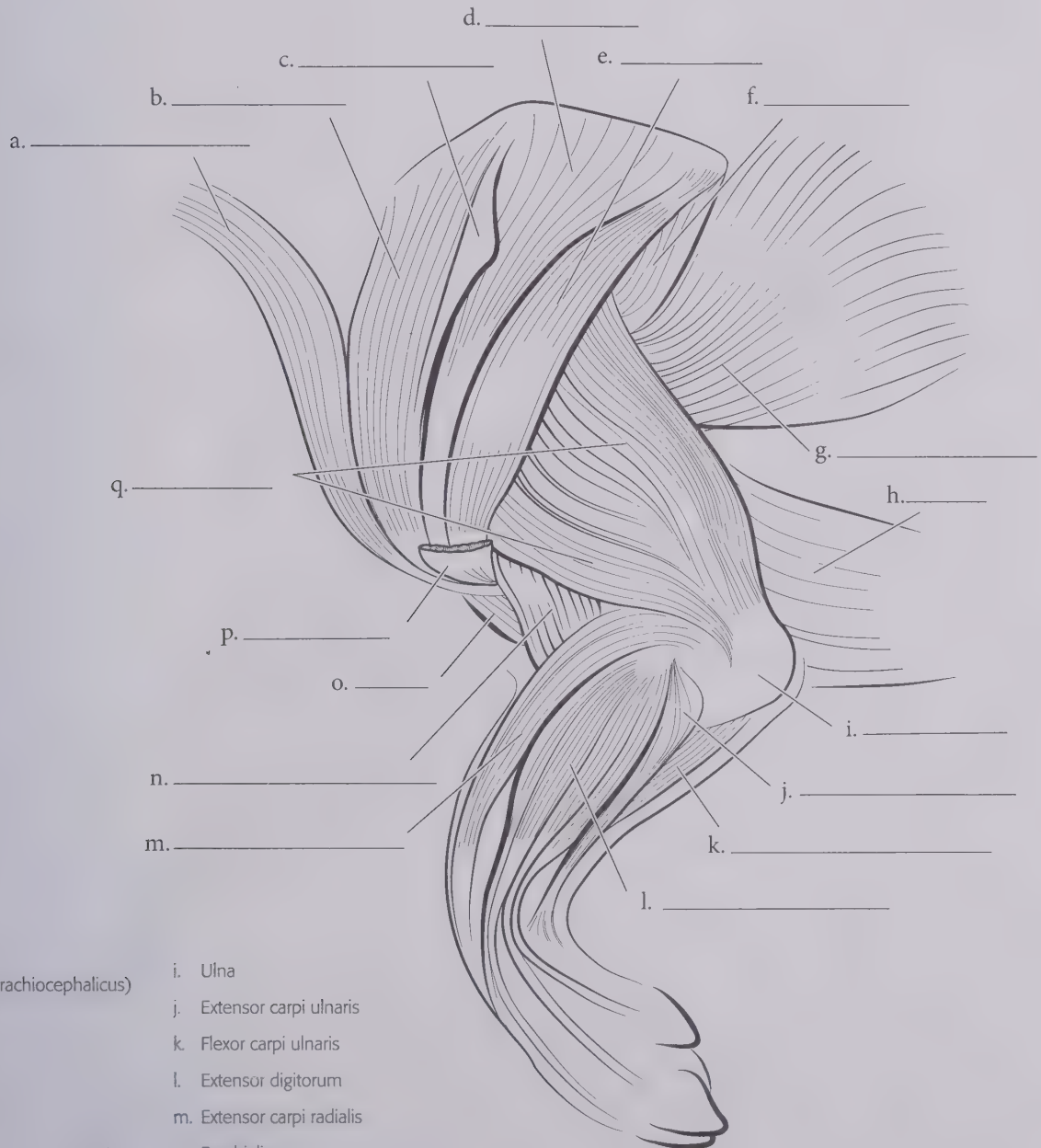
Answer Key:

- a. Acromiotrapezius muscle
- b. First thoracic vertebra
- c. Spinotrapezius muscle
- d. Triceps muscle
- e. Latissimus dorsi muscle
- f. Spinous processes of vertebrae
- g. Iliac crest of hip bone
- h. Tensor fasciae latae muscle
- i. Gluteus medius muscle
- j. Gluteus superficialis muscle
- k. Biceps femoris muscle

LATERAL FORELIMB

The brachiocephalic muscle originates in the neck while the deltoid originates on the scapula; both insert on the humerus and help to adduct the forelimb. On the ventral side, the **pectoralis minor** originates on the sternum and inserts on the humerus, also adducting the forelimb. The latissimus dorsi inserts on the humerus, but its origin spreads out over the back and it functions to abduct the forelimb. The **teres major** and **teres minor** both originate on the caudal portion of the scapula and insert with the latissimus dorsi on the humerus, also abducting the forelimb. The **supraspinatus** and **infraspinatus** originate on different sides of the scapular spine and both insert on the humerus; the supraspinatus extends the humerus while the infraspinatus rotates the humerus.

The **triceps** originates on both the scapula and the humerus and inserts on the ulna via a tendon that passes over the elbow, resulting in extension of the lower forelimb. The opposite action arises from the biceps which originates in the pig on the scapula via a tendon that passes over the groove on the cranial end of the humerus and inserts on both the radius and ulna to flex the lower forelimb. A group of extensor and flexor muscles originates on the humerus and inserts on various digits, metacarpals, and the radius to control extension, flexion, and rotation of the foot.



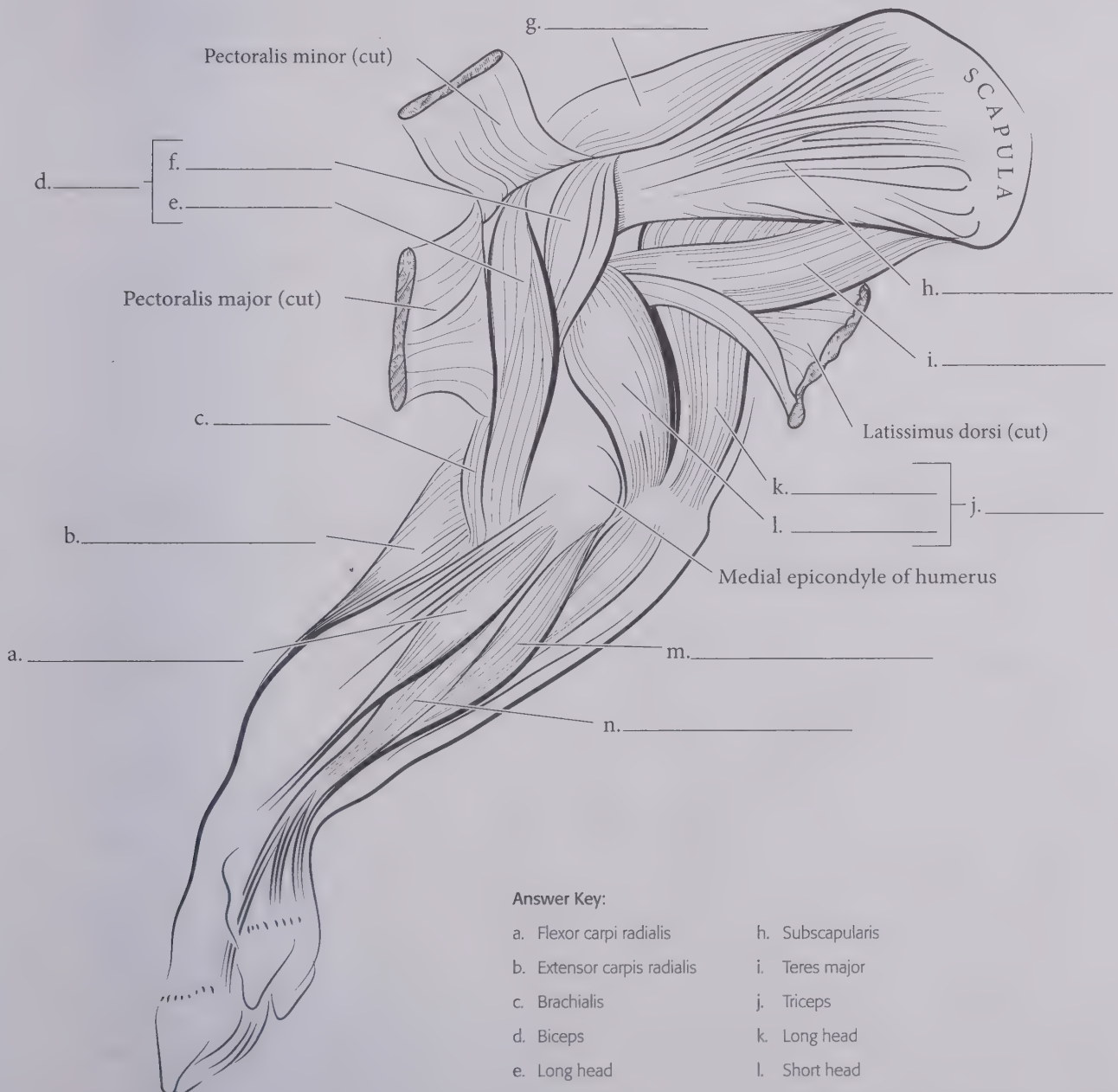
Answer Key:

- | | |
|---|----------------------------|
| a. Brachiocephalic (Brachiocephalicus) | i. Ulna |
| b. Supraspinatus | j. Extensor carpi ulnaris |
| c. Spine of scapula | k. Flexor carpi ulnaris |
| d. Infraspinatus | l. Extensor digitorum |
| e. Teres minor | m. Extensor carpi radialis |
| f. Teres major | n. Brachialis |
| g. Latissimus dorsi | o. Biceps |
| h. Pectoralis minor
(Pectoralis profundus) | p. Deltoid (cut) |
| | q. Triceps |

MEDIAL FORELIMB

Originating from the medial surface of the scapula, between the supraspinatus and teres major, the **subscapularis** is a thick muscle that inserts on the humerus and acts to adduct the forelimb. Deep to the **pectoralis major** and pectoralis minor (see ventral view of muscular system) can be found the insertion of the **biceps**, so named because it has two insertion points on the scapula. The biceps inserts on both the radius and ulna, acting to flex the lower forelimb. Near the biceps is the brachialis, which originates on the humerus, inserts on the ulna, and also acts to flex the lower forelimb. The triceps has multiple origins on the humerus and scapula, inserts on the ulna, and functions to extend the lower forelimb.

Use the lateral and medial views of the forelimb to construct a mental three-dimensional image of the muscle placements and actions. For each muscle action, pair it in your mind with another muscle that returns the limb to its original position. Use the same colors for a single muscle regardless of the illustration in which it is shown—many can be seen (at least in part) in multiple images.



Answer Key:

- | | |
|----------------------------|--|
| a. Flexor carpi radialis | h. Subscapularis |
| b. Extensor carpi radialis | i. Teres major |
| c. Brachialis | j. Triceps |
| d. Biceps | k. Long head |
| e. Long head | l. Short head |
| f. Short head | m. Deep digital flexor (Flexor digitorum profundus) |
| g. Supraspinatus | n. Superficial digital flexor (Flexor digitorum superficialis) |

HIND LIMB

Although the muscles of the forelimb and hind leg have many similarities (note the biceps in the forelimb and the biceps femoris in the hindlimb, for example), there are also differences associated with the distinctive movements.

Unlike the pectoral girdle, the hind legs are attached to the axial skeleton at the pelvis; muscles originate there to move the hind legs. The tensor fasciae latae originates on the pelvis and inserts on the fascia near the knee, both extending the lower leg and protracting the thigh. The biceps femoris originates on the pelvis and inserts along the length of the tibia; it acts to flex the lower leg and retract the thigh. The gluteus superficialis originates on the caudal and sacral vertebrae, inserts on the femur, and acts to abduct and extend the thigh. The **gluteus medius** originates on the pelvis and inserts on the femur to retract and abduct the thigh. The semitendinosus and semimembranosus both originate on the pelvis; the semitendinosus inserts on the tibia and retracts the thigh and flexes the lower leg, along with the biceps femoris. The semimembranosus inserts on the distal part of the femur and adjacent portions of the tibia; it acts

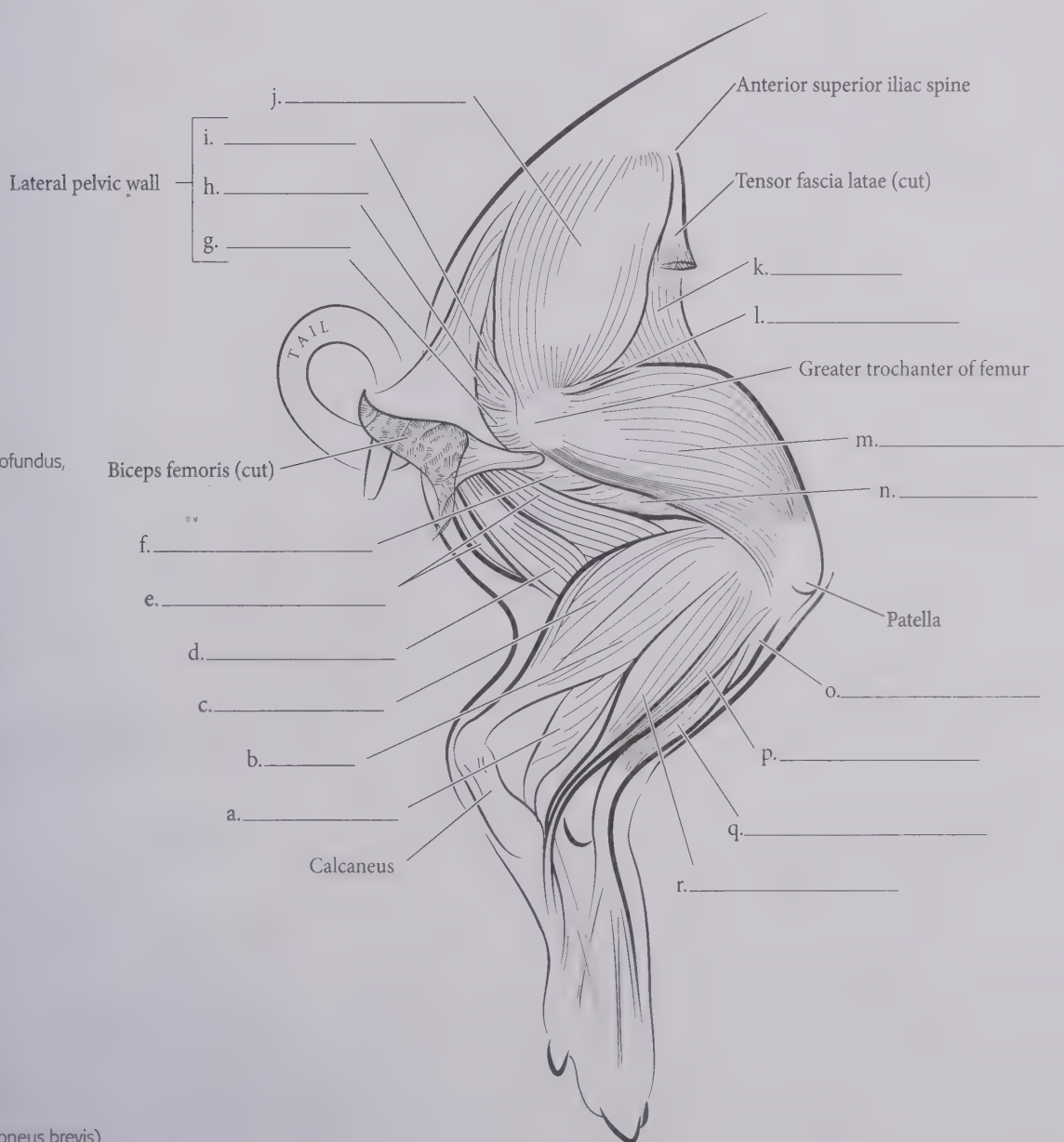
to retract the thigh. Several muscles, including the **rectus femoris** and the **vastus lateralis** originate on the femur, insert on the patella, and act to extend the leg and/or flex the thigh.

Lying deep to the gluteus medius are a number of muscles acting to rotate and retract the leg, including the **iliopsoas**, **quadratus femoris**, adductor, **piriformis**, **superior gemellus**, and **obturator**. Most of these originate on vertebrae or a portion of the pelvis and insert on a part of the femur.

The **gastrocnemius** originates along the femur, and the **soleus** originates on the head of the fibula; both insert on the Achilles tendon and the largest tarsus bone, the calcaneus, and act to extend the foot. The **tibialis anterior** originates on the tibia, inserts on metatarsals, and acts to flex the foot. Further movement of the foot is controlled by a group of digital extensors and flexors, each of which originates on the proximal end of the tibia or fibula and inserts on the digits or metatarsals.

Answer Key:

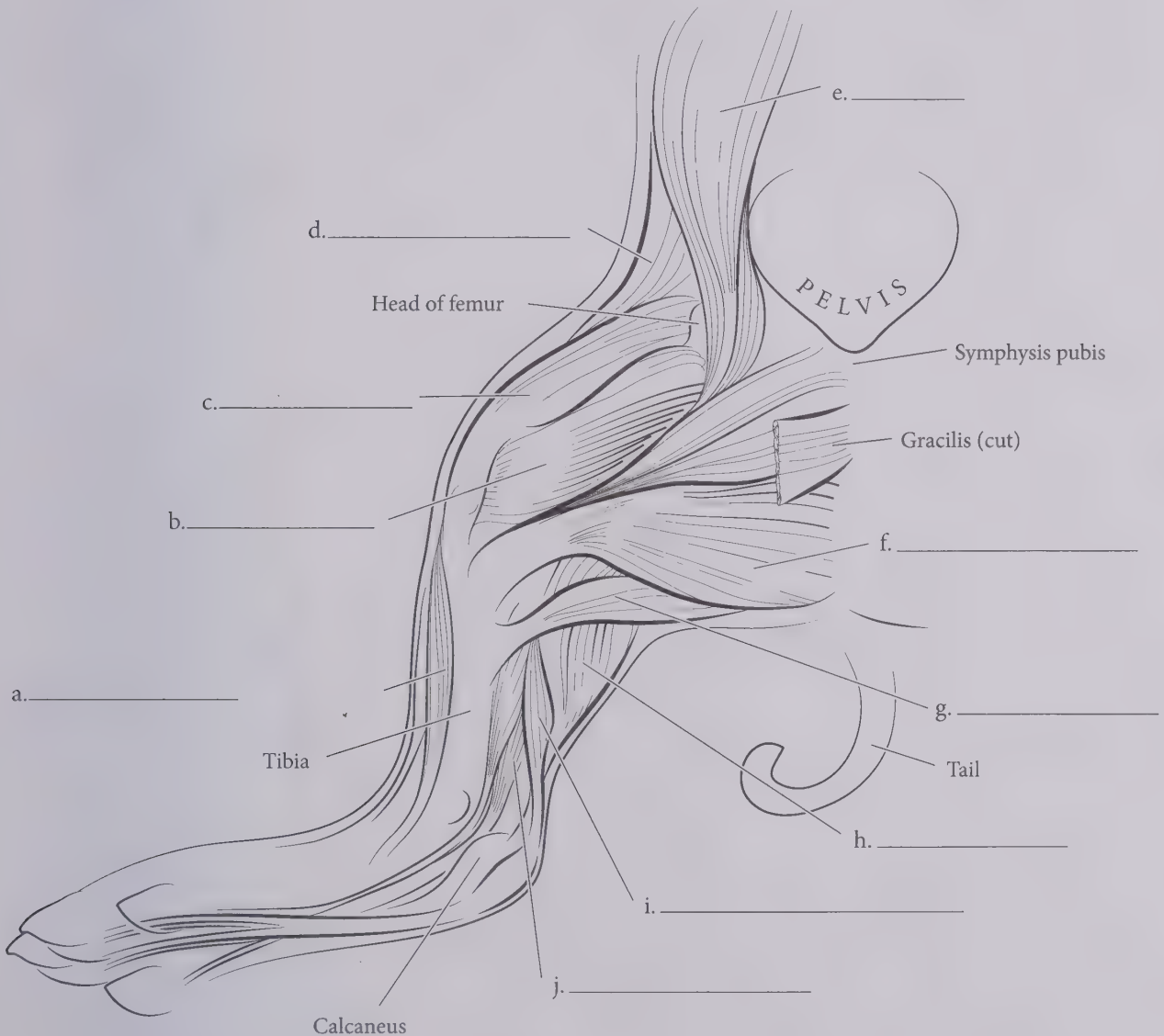
- a. Deep digital flexor
(Flexor digitorum profundus,
Tibialis posterior)
- b. Soleus
- c. Gastrocnemius
- d. Semitendinosus
- e. Semimembranosus
- f. Quadratus femoris
- g. Obturator
- h. Superior gemellus
- i. Piriformis
- j. Gluteus medius
- k. Iliopsoas
- l. Rectus femoris
- m. Vastus lateralis
- n. Adductor
- o. Tibialis anterior
- p. Fibularis longus
(Peroneus longus)
- q. Extensor digitorum
- r. Fibularis brevis (Peroneus brevis)



MEDIAL HIND LIMB

Deep to the gracilis, the medial view of the hind leg shows the full extent of some of the muscles described in the preceding illustration, where only part was shown. Use the lateral and medial views of the hind leg to construct a mental three-dimensional image of the muscle placements and actions. Together with the rectus femoris and vastus lateralis muscles described previously, the **vastus medialis** shown here and the deeper vastus intermedius (not shown) make up the group of muscles known as the quadriceps femoris.

For each muscle action, pair it in your mind with another muscle that returns the limb to its original position. Use the same colors for a single muscle regardless of the illustration in which it is shown—many can be seen (at least in part) in multiple images.



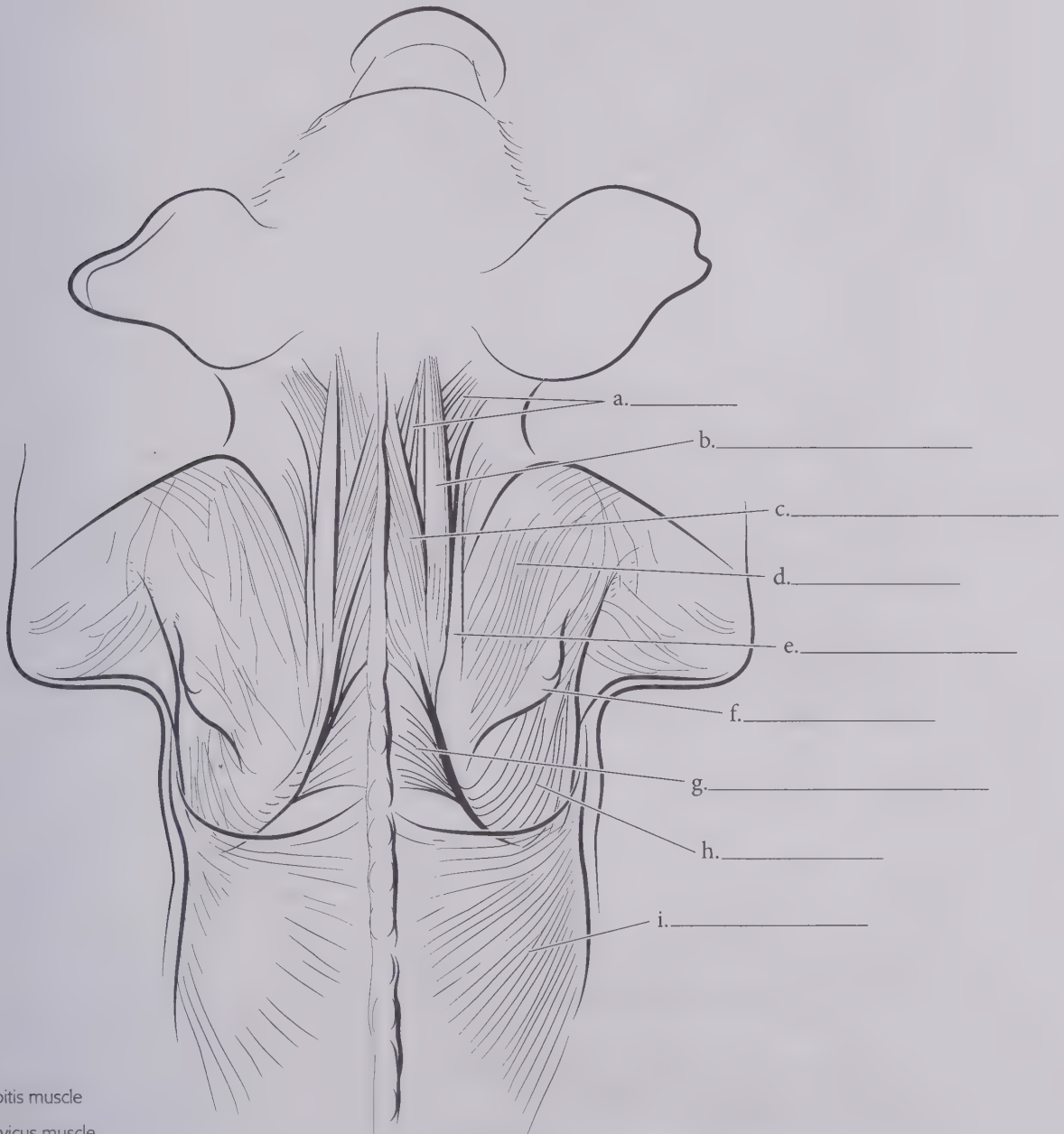
Answer Key:

- | | |
|--|--|
| a. Tibialis anterior
(Tibialis cranialis) | f. Semimembranosus |
| b. Vastus medialis | g. Semitendinosus |
| c. Rectus femoris | h. Gastrocnemius |
| d. Tensor fasciae latae | i. Superficial digital flexor
(Flexor digitorum superficialis) |
| e. Iliopsoas | j. Deep digital flexor (Flexor digitorum
profundus, Tibialis posterior) |

DORSAL DEEP SHOULDER AND NECK MUSCLES

Muscles of the neck and back that are deep to the trapezius muscles include the **splenius** that originates on the spinous processes of cervical and thoracic vertebrae and inserts on the mastoid process where the mandible intersects with the skull; it elevates and rotates the head. The **rhomboideus capitis** and **rhomboideus cervicus** muscles originate at

the back of the skull or the spines of the cervical/thoracic vertebrae and insert on the vertebral border of the scapula, functioning to move the scapula toward the middorsal line. Other muscles that originate on the scapula function in movement of the forelimb.

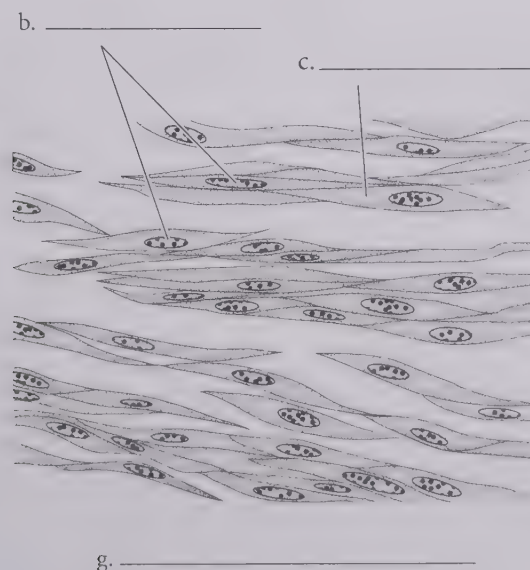
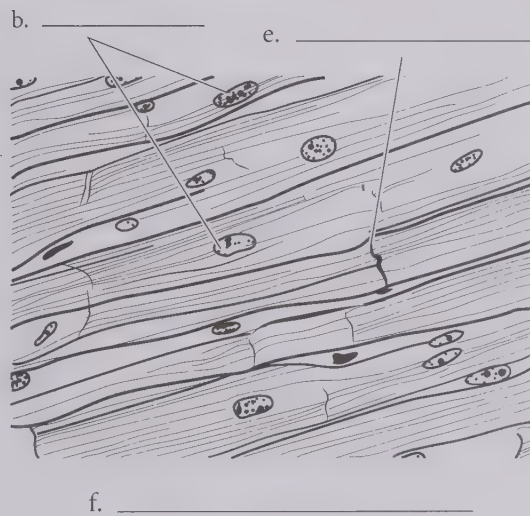
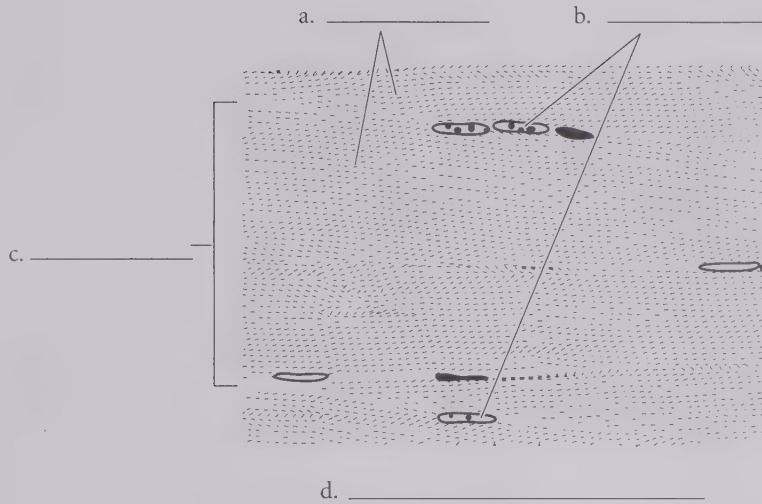


Answer Key:

- a. Splenius muscle
- b. Rhomboideus capitis muscle
- c. Rhomboideus cervicus muscle
- d. Supraspinatus muscle
- e. Serratus ventralis muscle
- f. Spine of scapula
- g. Rhomboideus thoracis muscle
- h. Infraspinatus muscle
- i. Latissimus dorsi muscle

MUSCLE HISTOLOGY

Skeletal or striated muscle is composed of cells, or fibers, that are formed by fusion of multiple myoblasts resulting in cells that are very long and often contain multiple nuclei lying just below the cell membrane. Note the alternating light and dark bands that form the striations which occur because of the highly organized, geometric arrangement of the actin and myosin proteins that do the work of contraction. Thicker myosin filaments are found only in the dark bands, while the thinner actin filaments compose the light bands and extend into the dark bands on either side. Although cardiac muscle in the heart is also striated, the bands are not as obvious. Individual cardiac muscle cells may branch; they contact adjoining cells tightly at specialized junctions called intercalated discs. Smooth muscle cells also contain actin and myosin for contraction, but they are not organized into structures that result in the obvious striations seen in skeletal muscle. These spindle-shaped cells are more suited to the slow, sustained contractions needed, for example, to move food through the digestive tract by peristalsis, or to constrict peripheral blood vessels in regulating blood pressure.



Answer Key:

- a. Striations
- b. Nuclei
- c. Cell
- d. Skeletal muscle
- e. Intercalated disc
- f. Cardiac muscle
- g. Smooth muscle

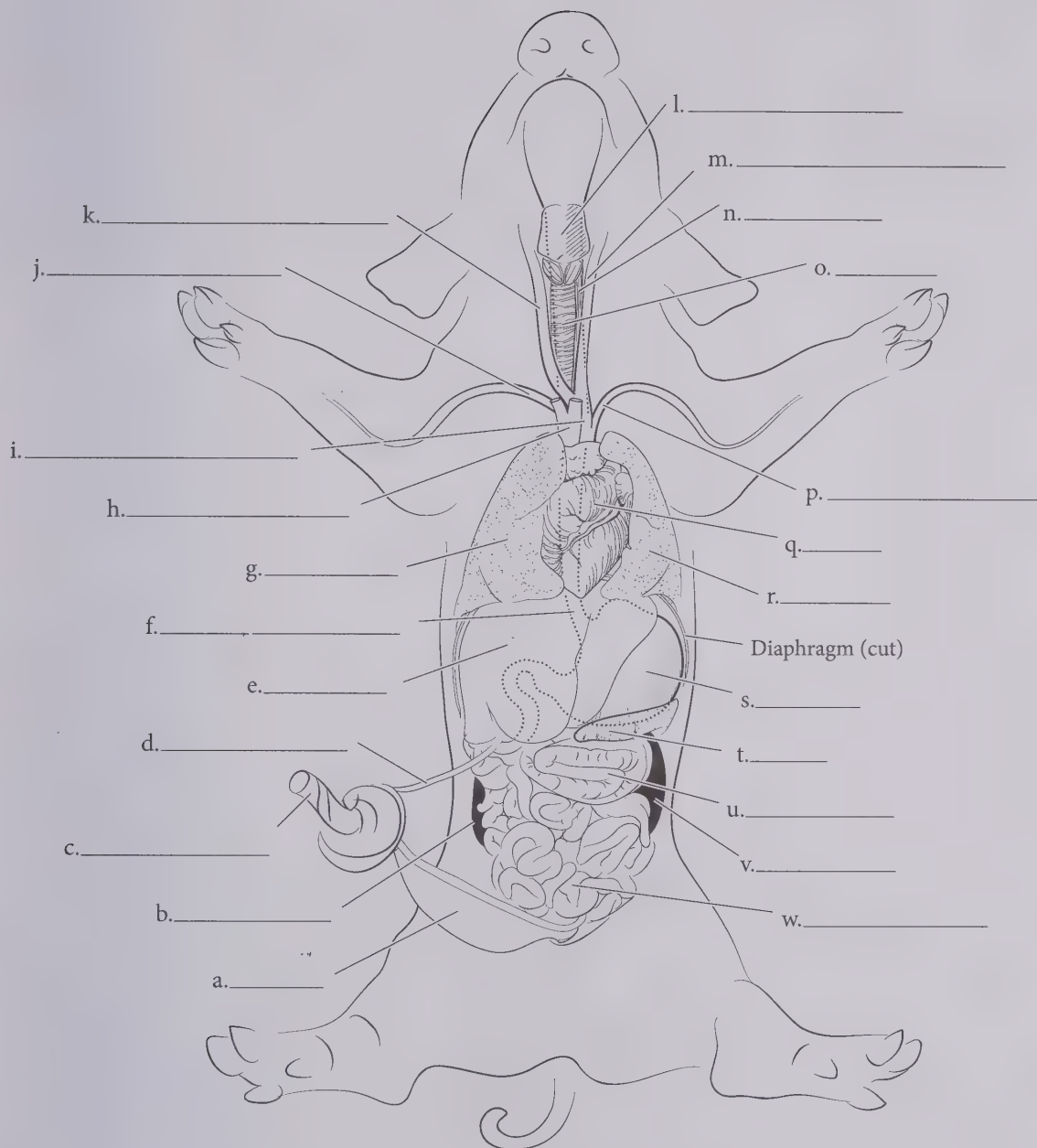
Like other mammals, the pig has an internal cavity within which many major organs develop, including those of the digestive, respiratory, circulatory, and excretory systems. In order to view these organs during dissection, one must carefully open the superficial layers of skin and muscle to reveal the organs beneath. Their arrangement in relation to one another is often important to their functions. Therefore, although we will examine each system in detail later, it is important that you understand how they fit together.

From the ventral aspect in the neck region, one can see the thyroid cartilage of the larynx and the trachea of the respiratory system, both located ventral to the esophagus which serves the digestive system. Nearby, blood vessels carry blood to the head region.

The large body cavity in the trunk, the coelom, is divided into two major regions by the **diaphragm**—a muscular organ of the respiratory system. The cranial portion is called the thoracic cavity and contains the heart and lungs, as well as many important blood vessels of the circulatory system and air passages of the respiratory system. The esophagus of the digestive system passes through the thoracic cavity dorsal to these other organs.

The caudal portion of the coelom is the abdominal cavity, which includes many organs of the digestive, excretory, reproductive, and endocrine systems. The esophagus emerges through the diaphragm into the stomach, and the digestive system continues with the small and large intestines. Accessory organs in the digestive system include the liver and pancreas. The excretory system includes paired kidneys which lie dorsal to the abdominal cavity, and the ventral urinary bladder, which is shown deflected away to reveal the other organs. The reproductive organs form in the abdominal cavity (female) or near the kidneys (male), but cannot be seen in this view. The only endocrine organ visible from this view is the pancreas, which contains endocrine tissue as well being a part of the digestive system.

In this overview diagram, you will find it useful to color the organs using a different color for each system. Begin to use the convention that arteries are colored bright red to denote oxygenated blood, while veins are colored bright blue to represent deoxygenated blood.



Answer Key:

- | | | |
|-----------------------|---|-----------------------------------|
| a. Bladder | h. Cranial vena cava (Superior vena cava) | p. Left subclavian artery |
| b. Right kidney | i. Brachiocephalic trunk | q. Heart |
| c. Umbilical cord | j. Right subclavian artery | r. Left lung |
| d. Umbilical vein | k. Right common carotid artery | s. Stomach |
| e. Liver | l. Thyroid cartilage | t. Spleen |
| f. Esophagus (dotted) | m. Left common carotid artery | u. Spiral colon (Large intestine) |
| g. Right lung | n. Esophagus | v. Left kidney |
| | o. Trachea | w. Small intestine |

Like humans, pigs are omnivores, and their digestive system is more like humans than other mammals. This means that the digestive system is optimized for ingesting and digesting both animal flesh and herbaceous materials. The digestive system is essentially a long tube running from the **mouth** where food is ingested, through specialized digestive regions such as the stomach and intestines, to the anus where undigested waste materials are eliminated; in all, the pig's intestinal tract is about 15 times the length of its body! From the mouth, food travels through the **esophagus** into the **stomach**, which is very acidic and begins the digestion of proteins. In the **small intestine**, most digestion of protein, carbohydrate, and fat occurs, as well as the nearly all absorption of these nutrients; it may be divided into three regions—a short duodenum, long jejunum, and short ileum. In the large intestine or **colon**, water is

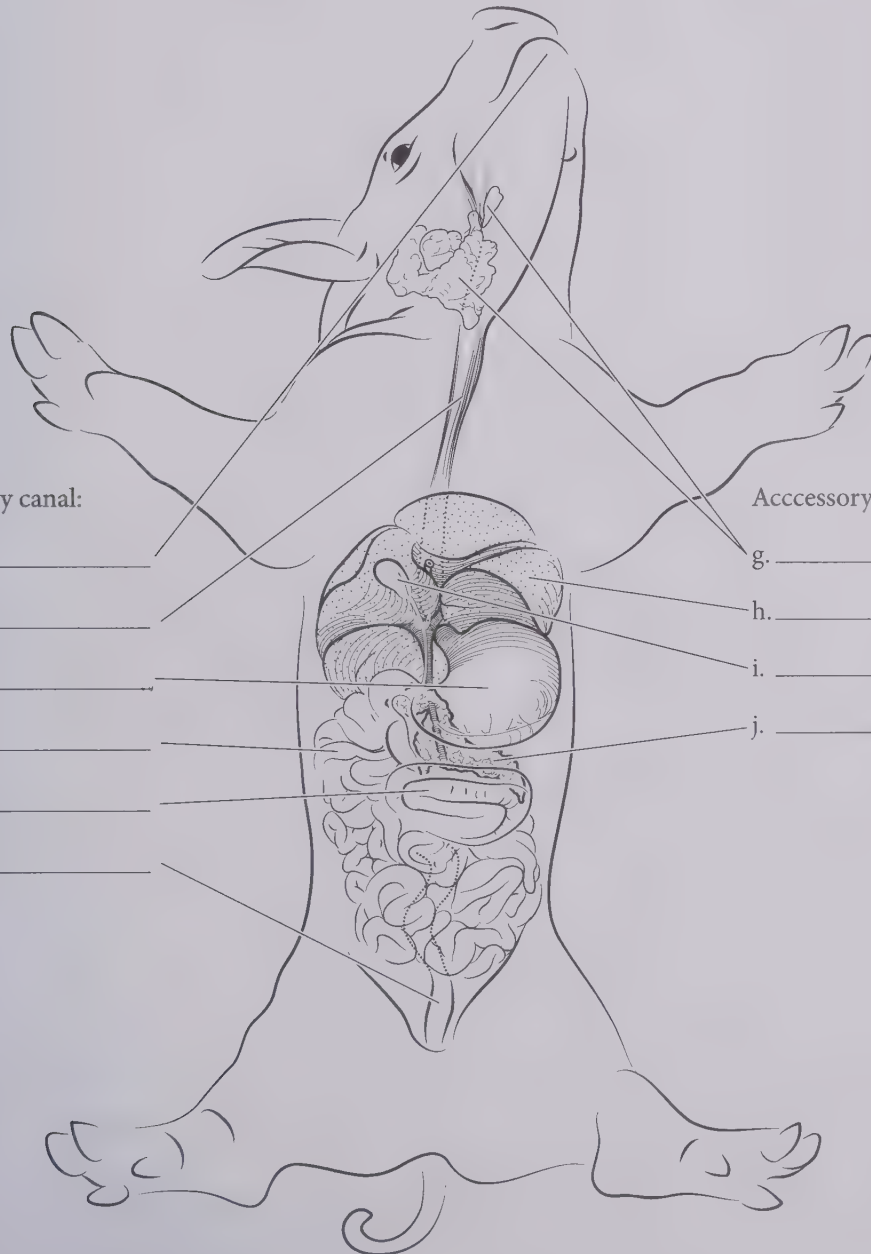
absorbed, microorganisms may break down some undigested nutrients, and the wastes are compacted for elimination. The pig's colon is structured differently from the human: Although relatively longer than that in humans, the pig's colon is not much larger in diameter than the small intestine. In addition, the ascending colon is arranged in a highly coiled structure called the **spiral colon**, which leads to the transverse and descending colon. The final straight stretch of colon before the anus is the **rectum**. The digestive system also includes the associated organs that assist in processing the food, such as the **liver**, **gall bladder**, and **pancreas**.

Alimentary canal:

- a. _____
- b. _____
- c. _____
- d. _____
- e. _____
- f. _____

Accessory organs:

- g. _____
- h. _____
- i. _____
- j. _____



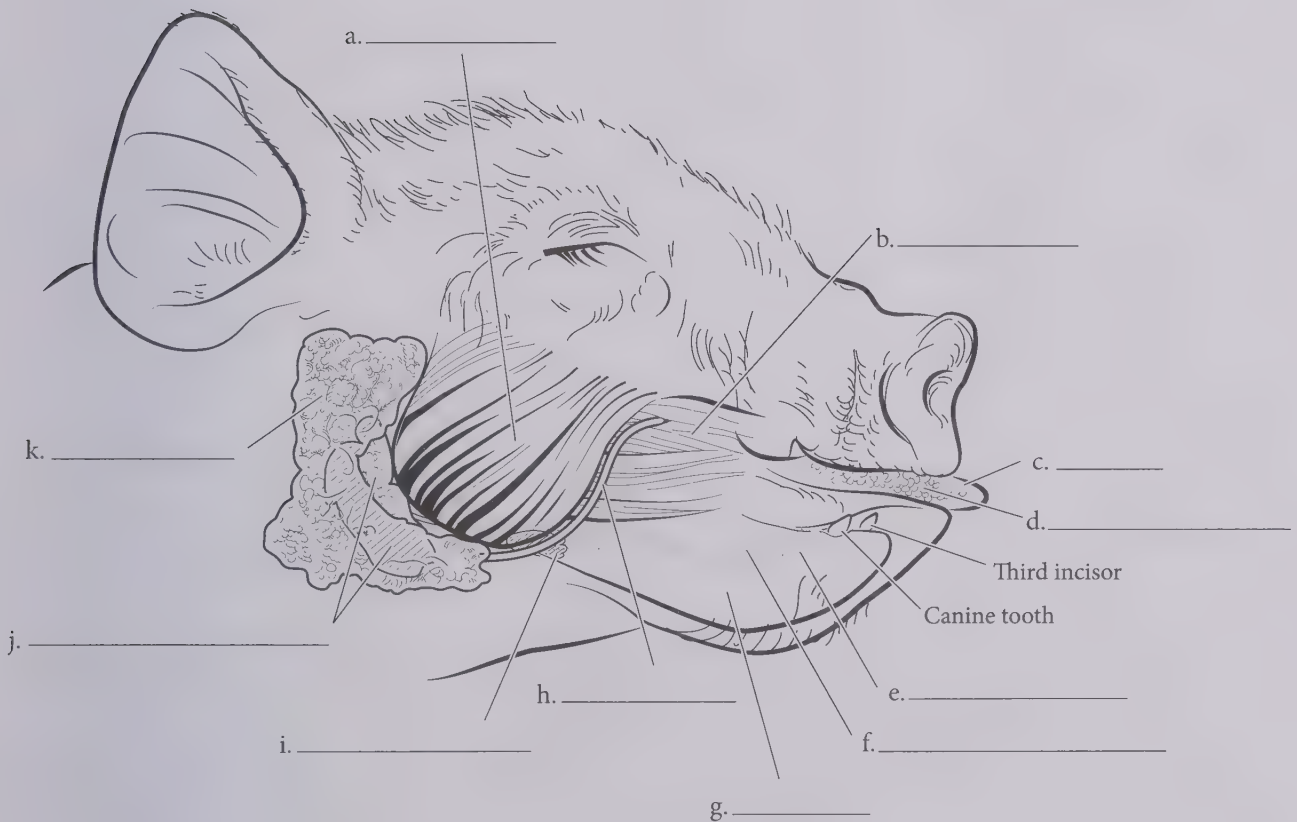
Answer Key:

- a. Mouth
- b. Esophagus
- c. Stomach
- d. Small intestine
- e. Large intestine
(Spiral colon, Colon)
- f. Rectum
- g. Salivary glands
- h. Liver
- i. Gall bladder
- j. Pancreas

SALIVARY GLANDS

Below the skin of the head are a number of structures that play a role while digestion is beginning in the mouth. Jaw muscles that provide power for biting and chewing include the **masseter** which closes the jaw and the **buccinator** which helps in closing the jaw as well as keeping the cheeks taut during chewing. Also important in biting and chewing are teeth; adult pigs have 42 teeth—three **incisors**, one **canine**, four **premolars**, and three **molars** on each side of the upper jaw; three incisors, one canine, three premolars, and three molars on each side of the lower jaw.

Salivary glands begin the process of digestion as food is chewed; saliva provides water to moisten food, mucus to lubricate food, salivary amylase to begin digesting starches, and antibacterial agents to kill microorganisms in the mouth. The parotid gland is located superficial to the masseter muscle; the **submandibular gland** is found deep to the parotid gland and posterior to the masseter; and the **sublingual gland** is located ventrally. Each has a duct to carry saliva from the gland into the oral cavity.



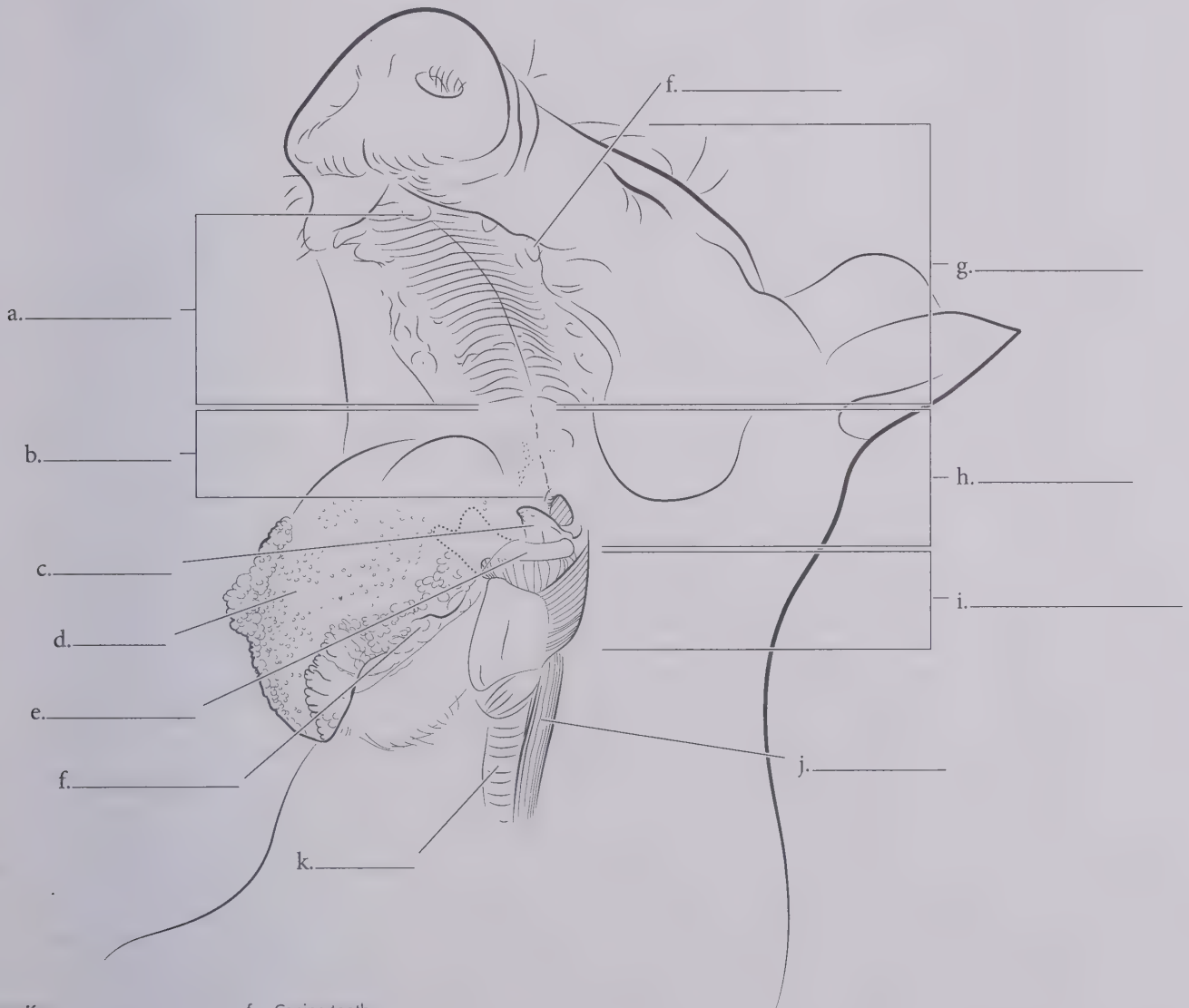
Answer Key:

- | | |
|-----------------------|---|
| a. Masseter muscle | g. Mandible |
| b. Buccinator muscle | h. Parotid duct |
| c. Tongue | i. Sublingual gland |
| d. Marginal papillae | j. Submandibular gland—deep to parotid gland (Mandibular, Submaxillary) |
| e. Sublingual duct | k. Parotid gland |
| f. Submandibular duct | |

ORAL CAVITY AND PHARYNX

Opening the oral cavity widely allows one to view the structure of this important portal to the digestive system, and to understand how it interfaces with the respiratory system. Food enters the oral cavity through the mouth, is chewed and formed into a compact mass by the teeth and **tongue**, and leaves the oral cavity through the esophagus. The throat, or **pharynx**, is a common passageway with regions that serve both the digestive and respiratory systems. The roof of the oral cavity is formed by the bony **hard palate** which separates it from the nasal cavity; the **soft palate** continues caudally—it separates the **nasopharynx** dorsally from the **oropharynx** below. The **laryngopharynx** is dorsal to the larynx and leads to the esophagus which carries food to the stomach.

The cartilaginous **epiglottis** prevents swallowed food from entering the **glottis**—the opening to the **larynx**, which then opens into the **trachea** or windpipe. The **hyoid** is a bone at the base of the tongue that supports and interacts with the cartilage of the larynx. Besides the teeth, the major structure in the oral cavity is the tongue, a muscular organ with taste buds located on its surface. Notice the marginal papillae that form a fringe-like edge to the tongue in the fetal pig and assist the newborn in suckling. As the pig's diet gradually changes from milk to solid food, the marginal papillae will regress.



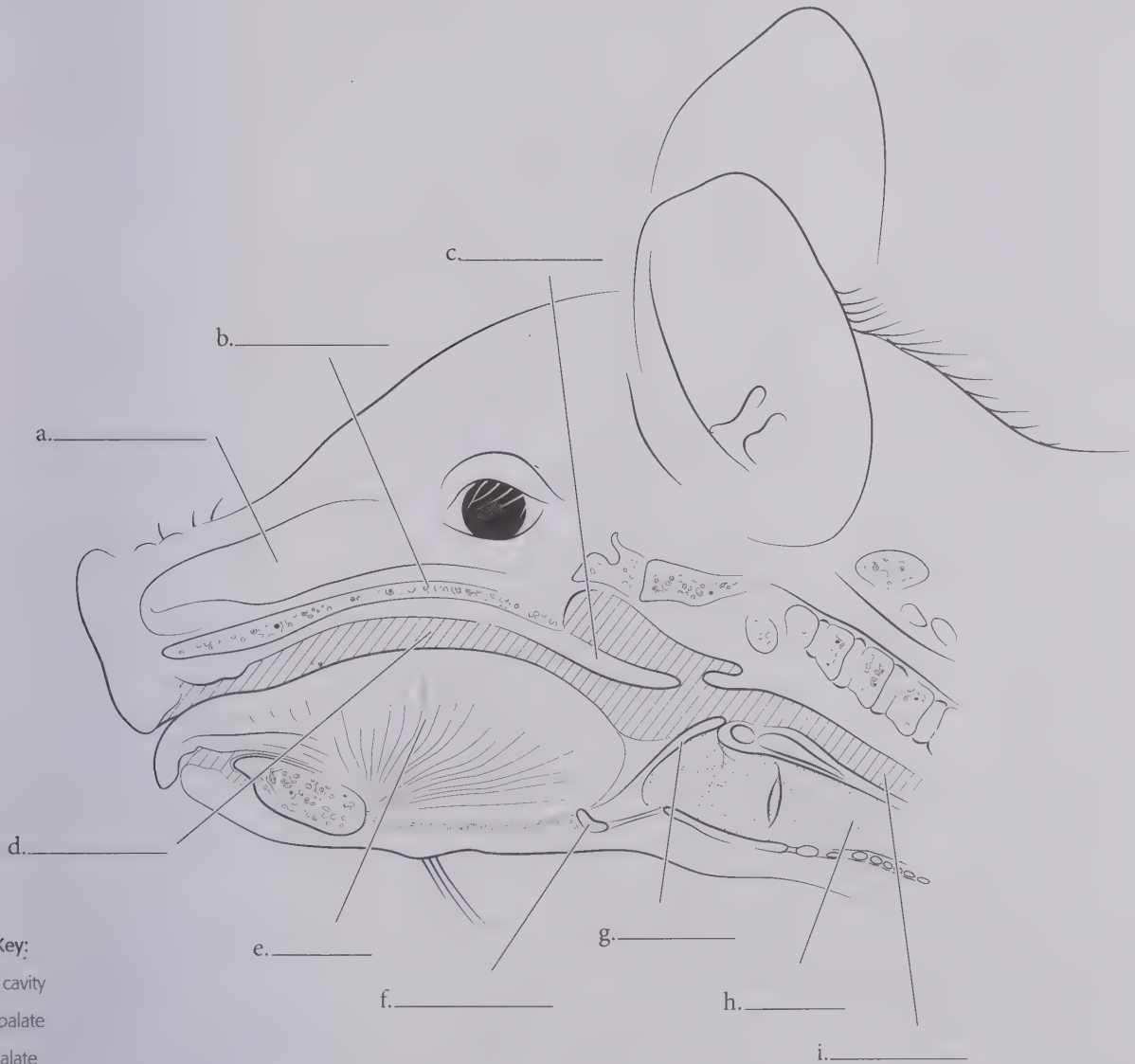
Answer Key:

- | | |
|----------------|-------------------|
| a. Hard palate | f. Canine tooth |
| b. Soft palate | g. Nasopharynx |
| c. Epiglottis | h. Oropharynx |
| d. Tongue | i. Laryngopharynx |
| e. Hyoid bone | j. Esophagus |
| | k. Trachea |

SAGITTAL SECTION HEAD AND NECK, SWALLOWING

A sagittal section provides another view of the digestive and respiratory systems in the head. Follow the paths of food and air during swallowing and breathing. During swallowing, muscles contract to raise the tongue so that it presses food and water against the hard palate. The tongue then elevates the soft palate and pushes the epiglottis over the glottis to partially close the laryngeal opening, as shown in this illustration. Pharyngeal muscles force food and water into the esophagus; smooth

muscle contractions there carry the material on to the stomach. Draw an arrow showing the path of food during swallowing, naming each region it moves through and the structures that influence its path. After swallowing is complete, the muscles at the base of the tongue relax, allowing the epiglottis to move forward again, and opening the glottis to air passage. Using another color, draw an arrow to show where air moves when the individual is not swallowing.

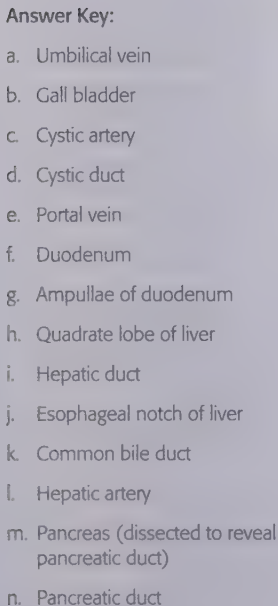


Answer Key:

- a. Nasal cavity
- b. Hard palate
- c. Soft palate
- d. Oral cavity
- e. Tongue
- f. Hyoid bone
- g. Epiglottis
- h. Trachea
- i. Esophagus

Accessory organs of the digestive system are shown from the ventral aspect, as they lie in the abdominal cavity adjacent to the small intestine. The largest organ of the abdomen is the liver; in the pig there are five lobes—right lateral, right central, left central, left lateral, and caudate. (In contrast the human has four lobes—right, left, caudate, and quadrate.) Nutrients absorbed during digestion are delivered first to the liver through the **hepatic portal vein**, which collects blood from the capillaries serving the intestines. The liver functions include detoxification of various chemicals; recycling of degraded red blood cell components; storage of excess glucose as glycogen; metabolism of carbohydrates, lipids, and proteins; and synthesis of plasma proteins, cholesterol, and bile. Between the right medial and quadrate lobes of the liver is the greenish-brown gall bladder; it functions to store bile made by the liver, and to release it

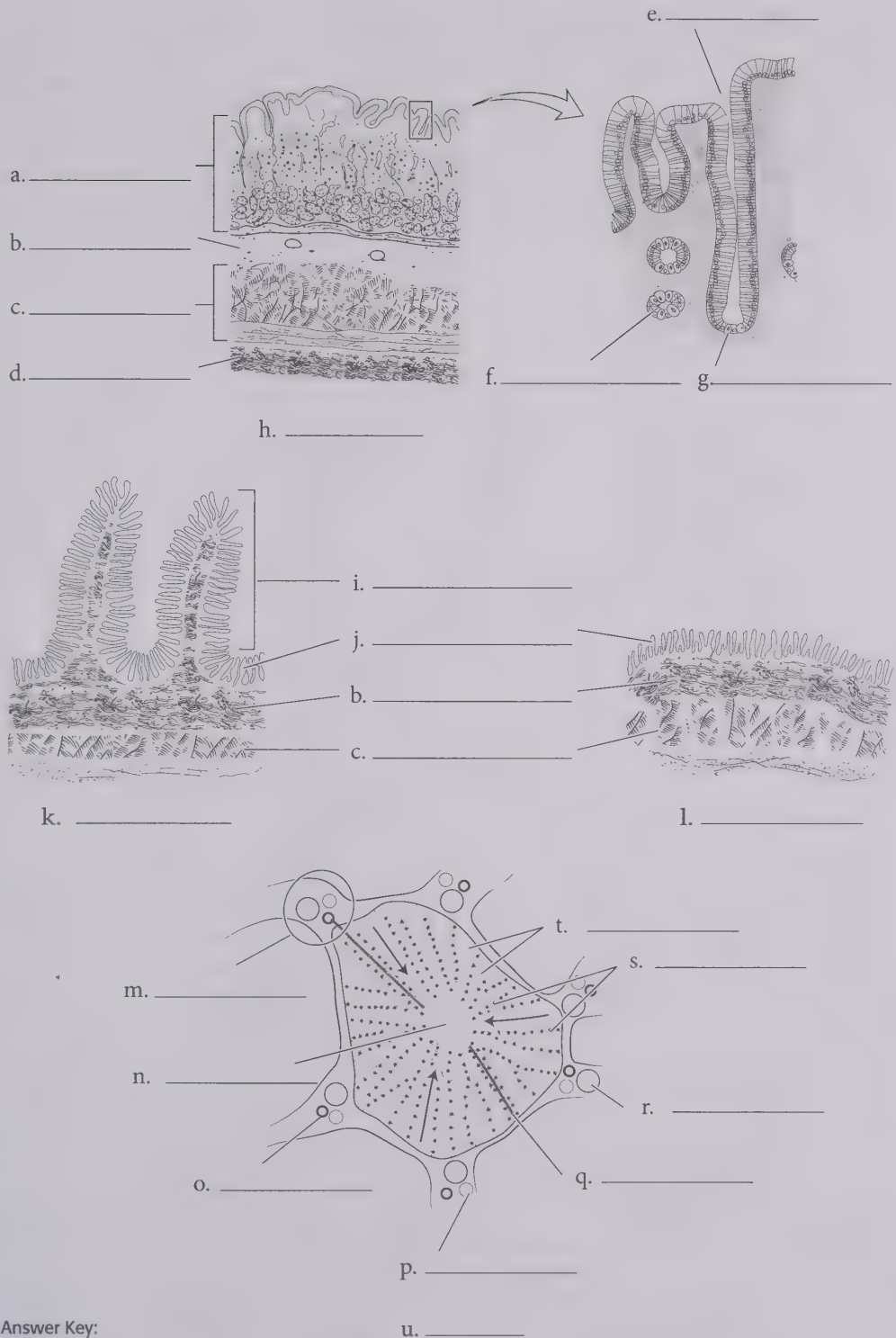
when needed for digestion and absorption of lipids in the small intestine. Bile drains from the gall bladder through the **cystic duct** to the **common bile duct** (which also drains the **hepatic duct** bringing bile directly from its synthesis in the liver) and then enters the **duodenum**, the first section of the small intestine. The pancreas is an elongated, granular organ lying between the stomach and the small intestine. The pancreas functions in digestion by secreting digestive enzymes and bicarbonate into the small intestine via the **pancreatic duct**. Another function of the pancreas is endocrine in nature—the islets of Langerhans scattered throughout the organ secrete insulin and glucagon directly into the bloodstream where they are carried throughout the body and function to lower and raise blood glucose, respectively; somatostatin is also secreted to regulate both insulin and glucagon levels.



DIGESTIVE SYSTEM HISTOLOGY

Although various regions of the digestive tract carry out different activities, they are composed of similar tissue layers—seen in a cross section, a thick layer of epithelial cells adjacent to the lumen is called the **mucosa**; under that is a layer called the **submucosa** that contains connective tissue and blood vessels; the **muscularis** is composed of smooth muscle; and the **serosa** (when present) is another layer of connective tissue on the outer edge of the digestive wall. The mucosa contains cells that secrete mucous throughout the digestive tract for lubrication and in the stomach cells secrete enzymes to digest proteins and HCl to acidify the stomach contents. Invaginations of the mucosa in the stomach are called gastric pits—the **chief cells** at the base of the pits secrete enzymes while the round **parietal cells** secrete HCl. In the small intestine, mucosal cells increase their surface area by folding into many projections called microvilli and the mucosa itself is highly folded into **villi** and even larger folds in the duodenum, also to increase the surface area available to absorb nutrients. The muscularis contains layers of muscle cells oriented in different directions—oblique, circular, and longitudinal. Waves of contraction of these muscles move food along through the digestive tract.

The liver is organized into small, hexagonal units called **lobules** arranged around a central vein, and with triads of vessels at the vertices—including branches of the portal vein bringing nutrient-rich blood from the intestines, the **hepatic artery** bringing oxygenated blood from the aorta, and the bile duct to remove the bile formed in the lobule. **Hepatocytes** are arranged within the lobule in plates—along the **bile canaliculus** on one side where they secrete bile they have synthesized, and **sinusoids** on the other side. Blood from the portal vein and hepatic artery pour into the sinusoid, is exposed to hepatocytes, and drains through the **central vein** to return to the vena cava. The cells also filter excess plasma from the sinusoids to produce lymph.

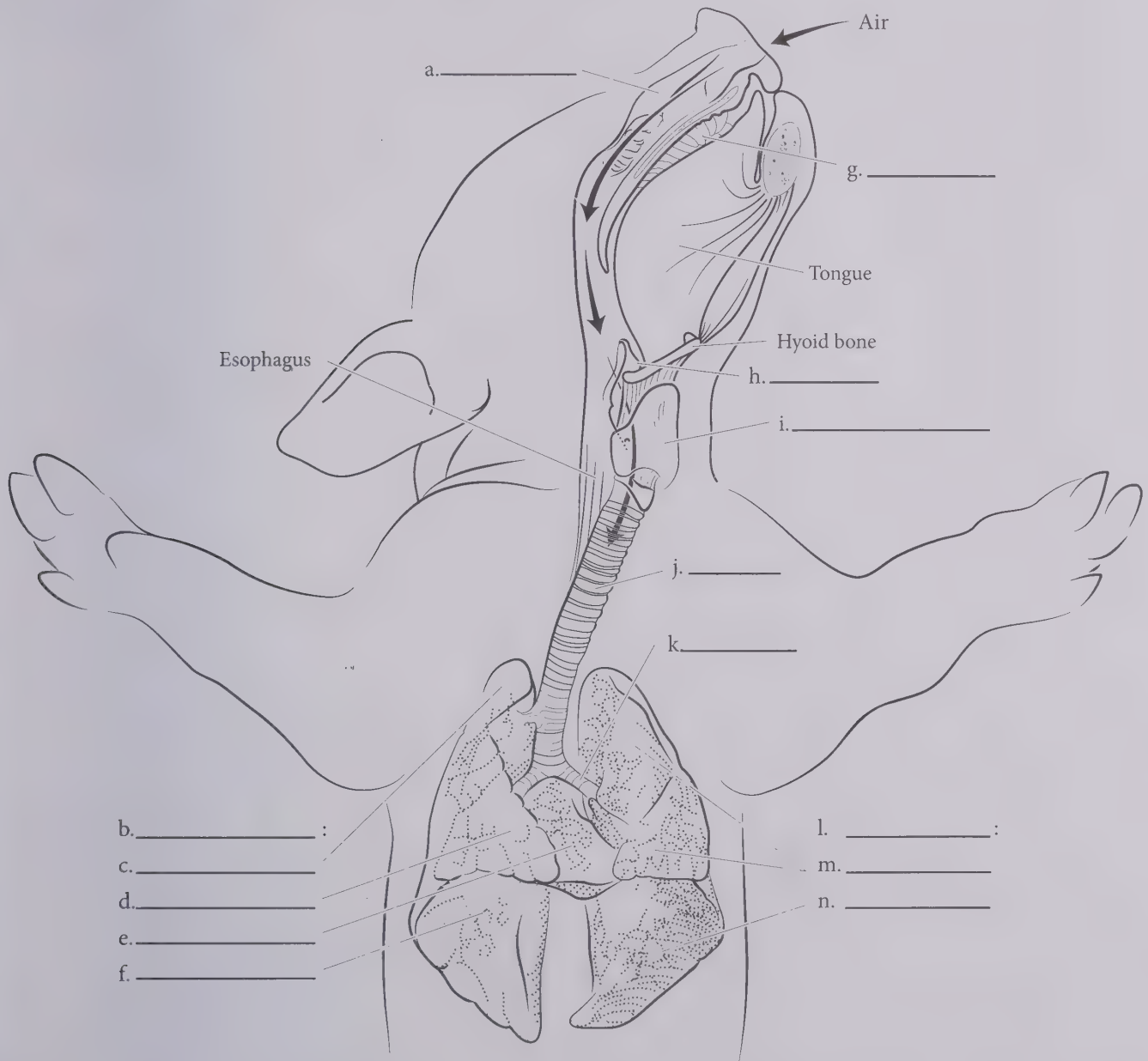


Answer Key:

- | | | |
|------------------|------------------|--------------------------|
| a. Mucosa | h. Stomach | o. Bile duct |
| b. Submucosa | i. Circular fold | p. Hepatic artery branch |
| c. Muscularis | j. Villus | q. Bile canaliculus |
| d. Serosa | k. Duodenum | r. Portal vein branch |
| e. Gastric pit | l. Ileum | s. Hepatocytes |
| f. Chief cell | m. Portal triad | t. Sinusoids |
| g. Parietal cell | n. Central vein | u. Liver |

The respiratory system is responsible for bringing oxygen into the **lungs** where it diffuses into the bloodstream, and for carrying off carbon dioxide waste. The respiratory system begins at the snout, where air enters the **nasal cavity** through the external nares. After passing through the pharynx, which is shared with the digestive system, air enters the trachea through an opening called the glottis. The glottis is protected by a flap of tissue—the epiglottis—which prevents food and water from entering the respiratory passages. After passing through the larynx, which contains the vocal cords and is protected by the thyroid cartilage, air enters the trachea. The trachea is held open for air passage by cartilaginous rings,

which are incomplete on the dorsal side. The trachea divides to form two **bronchii** for air to enter both of the paired lungs. As in humans, each lung is divided into lobes; in the pig, the right lung has four lobes instead of three, while the left has two lobes as in humans. The diaphragm is a bell-shaped muscle that completely separates the thoracic and abdominal cavities, by its attachment to the body wall in all directions. To function in breathing, the sheet-like diaphragm muscle contracts, moving it downward to enlarge the thoracic cavity. As the lungs expand with the thoracic cavity, air is drawn in. As the diaphragm relaxes and space for the lungs decreases, air is forced out.



Answer Key:

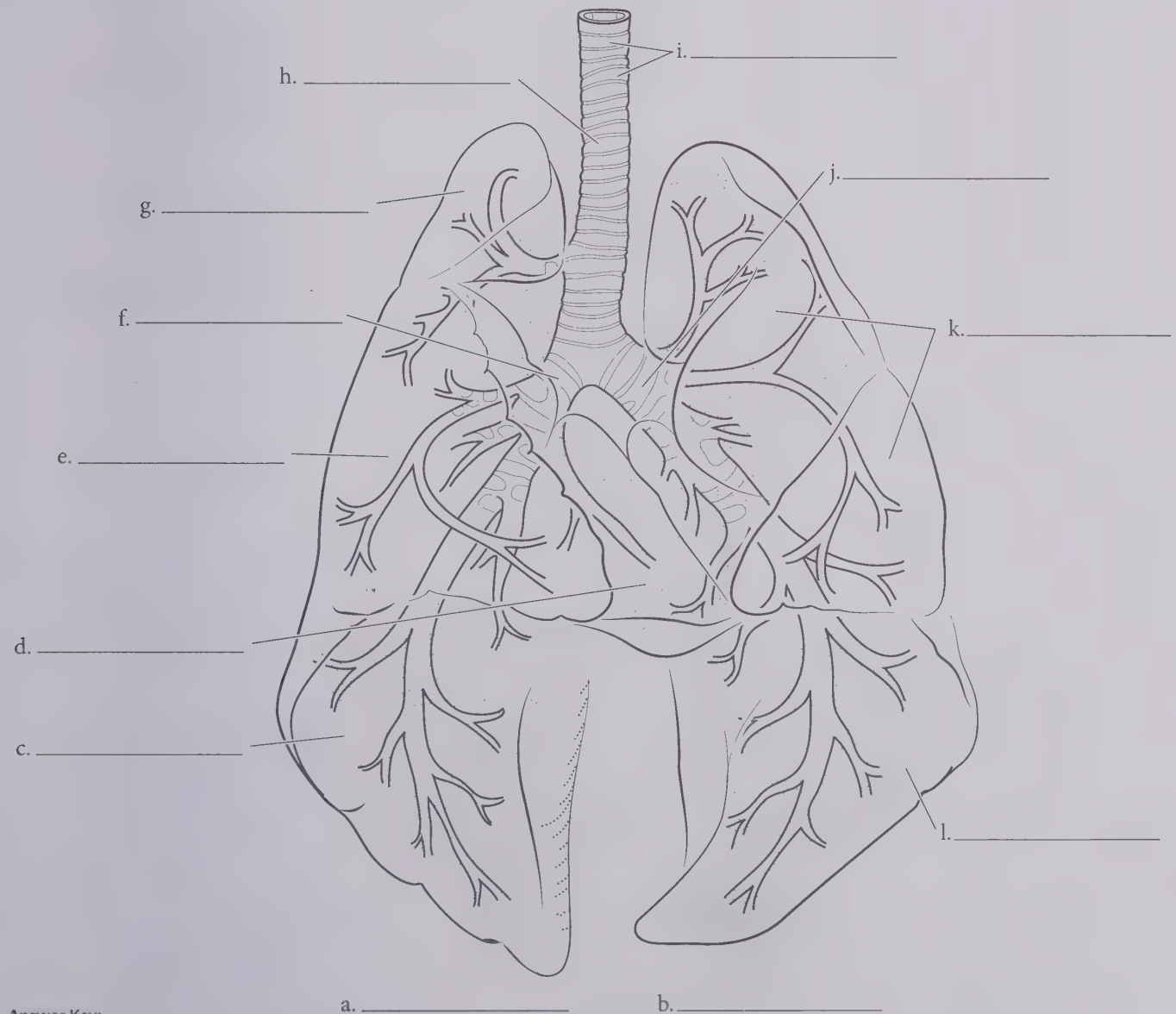
- a. Nasal cavity
- b. Right lung
- c. Cranial lobe
- d. Middle lobe

- e. Caudal lobe
- f. Accessory lobe
- g. Oral cavity
- h. Epiglottis
- i. Thyroid cartilage

- j. Trachea
- k. Bronchus
- l. Left lung
- m. Cranial lobe
- n. Caudal lobe

LUNG, TRACHEA, AND BRONCHI

The right lung has four lobes—**cranial**, **middle**, **caudal**, and **accessory**, while the left has only two lobes—**cranial** and **caudal**, although the cranial lobe is divided by a deep fissure into two sections. In the fetal pig, this tissue is quite compact since the pig has never taken a breath and inflated the lungs. After birth, however, the lungs become quite spongy when air reaches all parts of the lung in a branching system of tubes, beginning with the trachea which brings air from the larynx into the thoracic cavity. The trachea divides into two bronchi which then branch into many **bronchioles** that eventually terminate in the **alveoli** where gas exchange takes place. The lungs are also liberally supplied with blood vessels—so that the blood can take up oxygen from the air and release waste carbon dioxide at the same time.

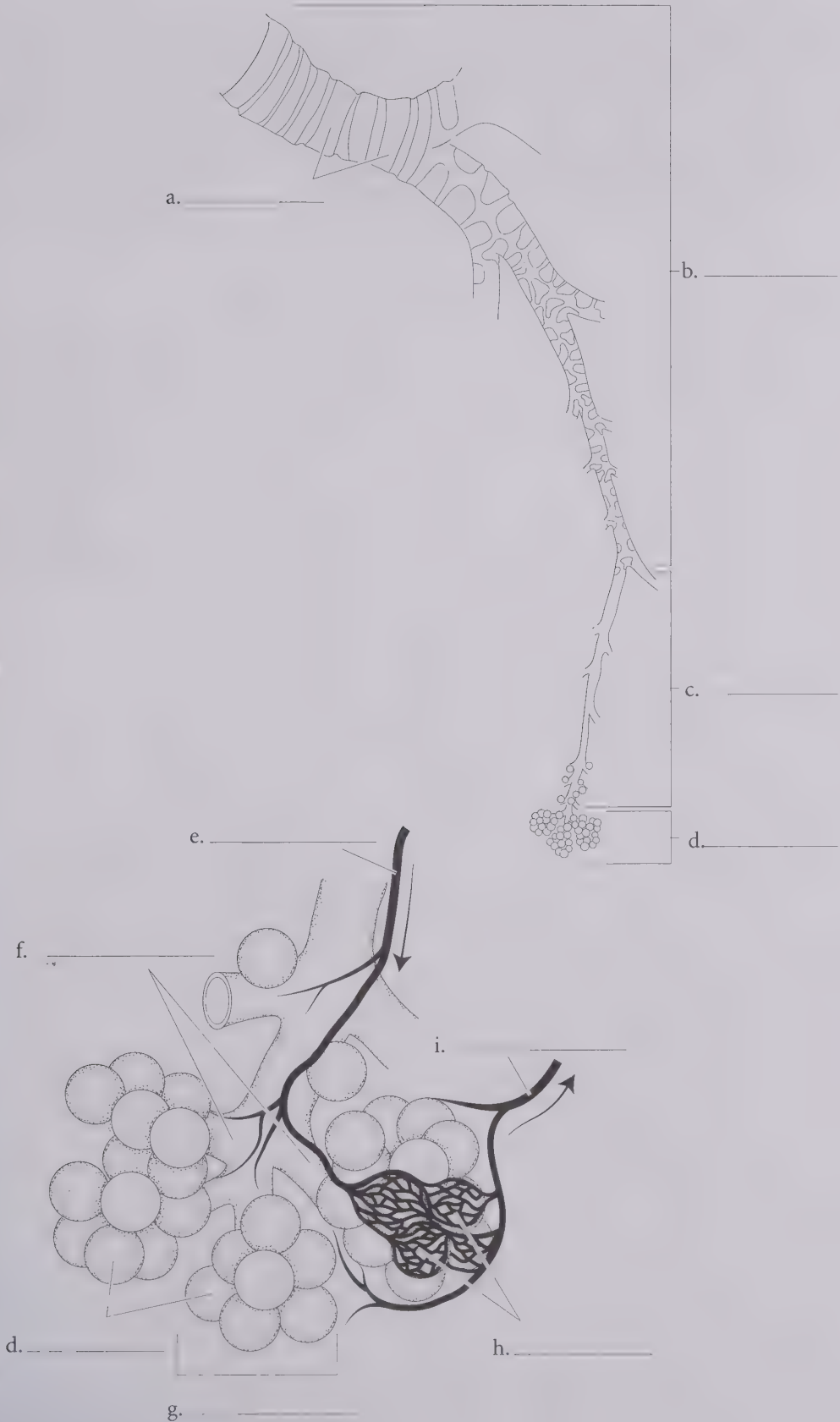


Answer Key:

- | | | |
|-------------------------|-----------------------|------------------------|
| a. Right lung | e. Right middle lobe | i. Tracheal cartilages |
| b. Left lung | f. Right bronchus | j. Left bronchus |
| c. Right caudal lobe | g. Right cranial lobe | k. Left cranial lobe |
| d. Right accessory lobe | h. Trachea | l. Left caudal lobe |

BRONCHI AND ALVEOLI

Large ducts such as the trachea and bronchi cannot maintain an open air passage without structural support from cartilage in their walls. The bronchial walls also have layers of smooth muscle and the lumen can expand or contract. Smaller bronchioles do not require cartilage for structural support and continue to branch until each branch of the bronchiole ends in a thin-walled chamber—the alveolus. The thin epithelial cells of the alveolus are in intimate contact with the thin-walled capillaries, allowing gas exchange to take place between the air in the alveolus and the blood in the capillaries. This oxygenated blood that has also been cleansed of excess carbon dioxide will return to the heart to be circulated to all tissues of the body for a fresh supply of oxygen. It is important to remember that, unlike the systemic circulation, pulmonary arteries carry deoxygenated blood (usually colored blue) while pulmonary veins carry oxygenated blood (usually colored bright red).



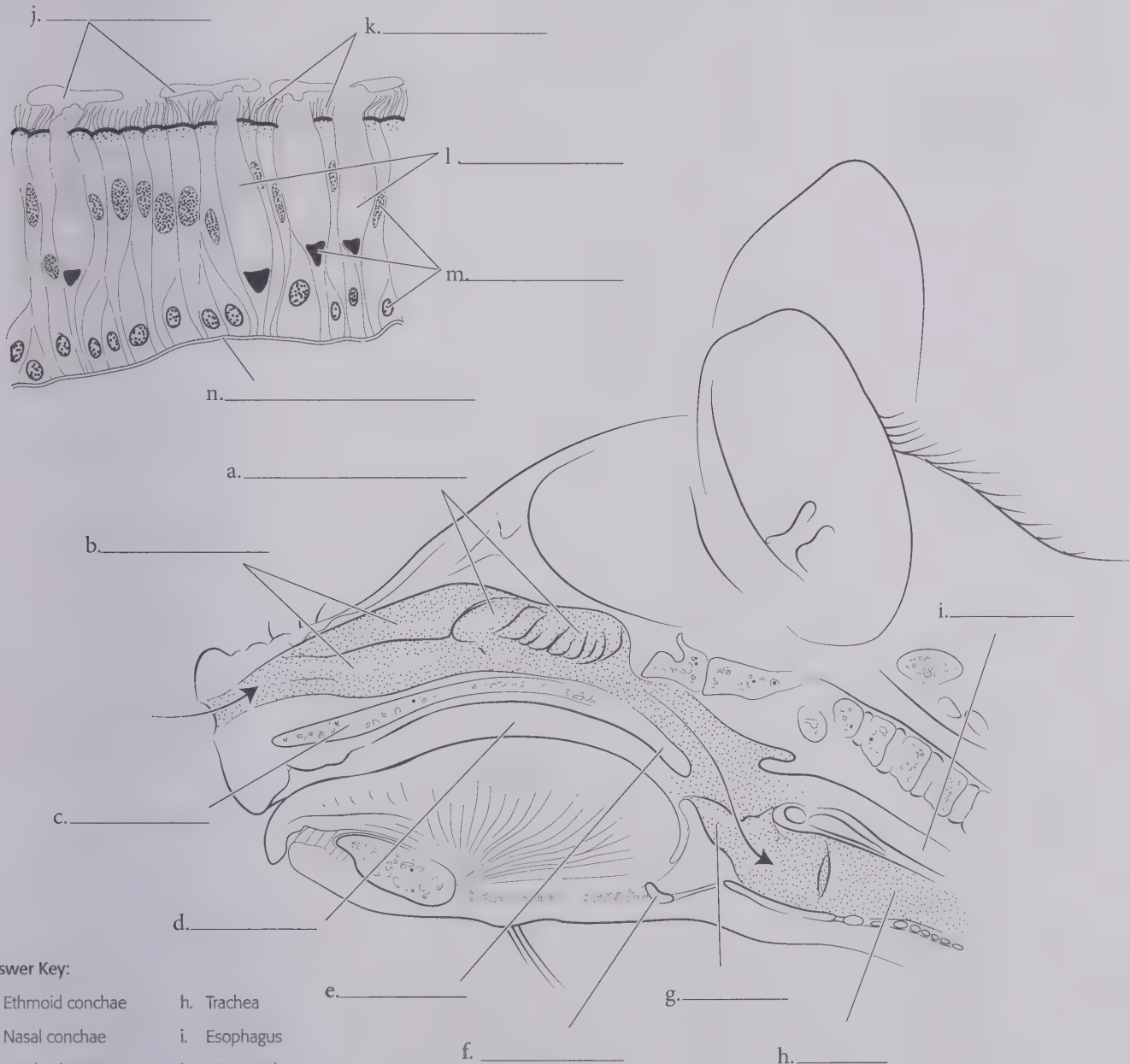
Answer Key:

- a. Cartilage
- b. Bronchi
- c. Bronchioles
- d. Alveoli
- e. Pulmonary artery
- f. Alveolar ducts
- g. Alveolar sac
- h. Capillaries
- i. Pulmonary vein

BREATHING AND HISTOLOGY

The path that air takes on its way to the lungs should be compared with the position shown earlier during swallowing in Chapter Six. Air is pulled into the respiratory system by contraction of the diaphragm, producing a negative pressure on the respiratory airways. Air entering the nostrils or nares passes over the **nasal conchae** and then the **ethmoidal conchae**. Inspired air is warmed and moistened as it passes over these mucous surfaces. Warm, moist air being expired may also return some of its water vapor on these surfaces. The ethmoid conchae, in particular, are a highly folded olfactory surface for detecting volatile chemicals, with far more surface area than found in humans (who do

not rely as heavily on sense of smell). Air passes into the pharynx, which is shared between the respiratory and digestive systems. When swallowing muscles are relaxed, the epiglottis moves forward, the soft palate moves down, and the air passes readily from the nasopharynx, through the laryngopharynx, to the glottis, through the larynx, and into the trachea. The epithelial cells that line the respiratory passages are liberally supplied with goblet cells that secrete mucous. Mucous traps dirt particles in the incoming air, and both mucous and dirt are moved away from the lungs by the hair-like protrusions called cilia that line these respiratory pathways.



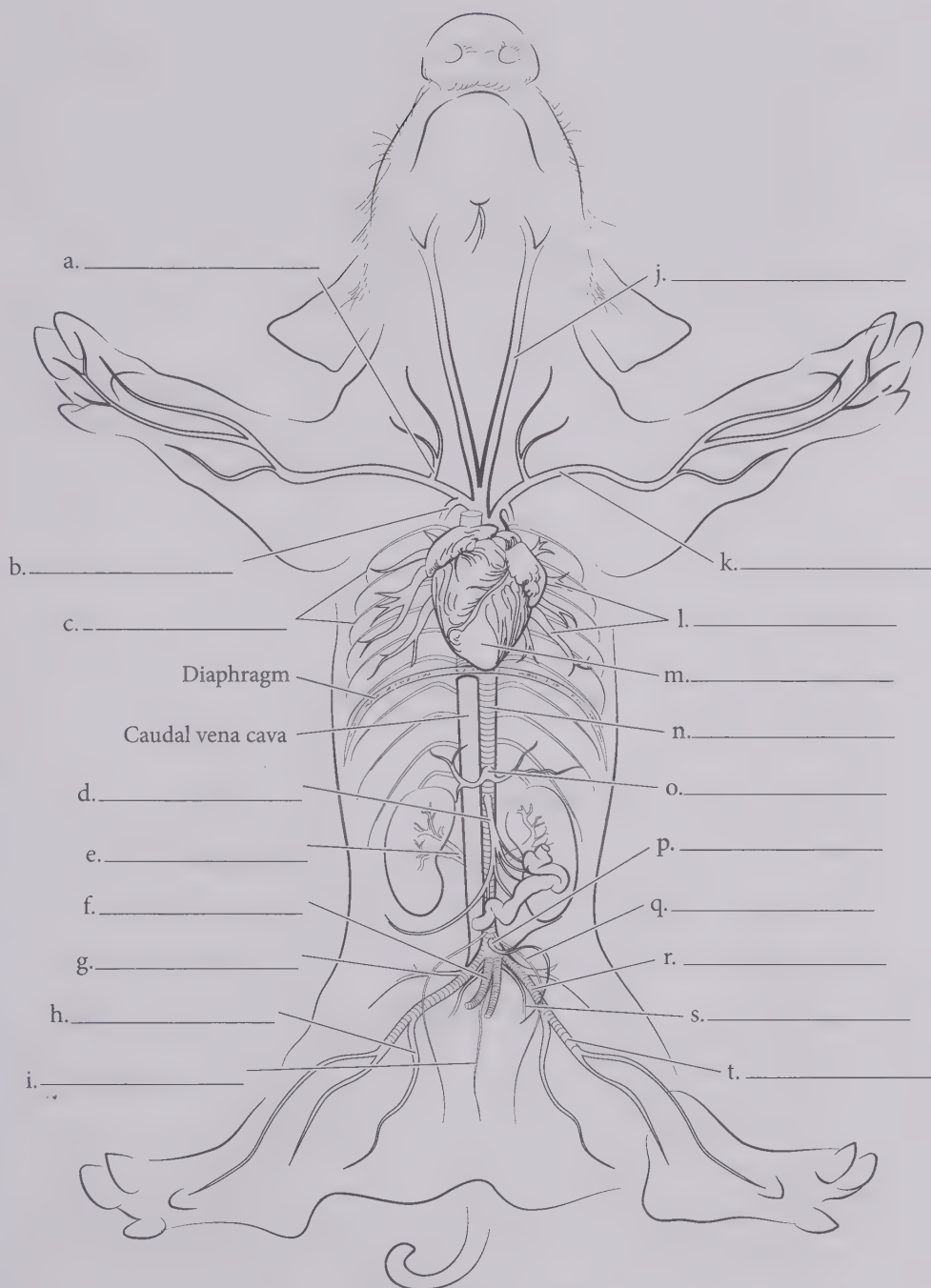
Answer Key:

- | | |
|--------------------|----------------------|
| a. Ethmoid conchae | h. Trachea |
| b. Nasal conchae | i. Esophagus |
| c. Hard palate | j. Mucous sheet |
| d. Oral cavity | k. Cilia |
| e. Soft palate | l. Goblet cells |
| f. Hyoid bone | m. Nuclei |
| g. Epiglottis | n. Basement membrane |

The circulatory system transports nutrients, oxygen, carbon dioxide, hormones, and dissolved waste products to and from individual cells. The circulatory system itself includes a four-chambered heart along with networks of vessels to carry blood between the heart and tissues throughout the body. Pigs have a double circulation—a pulmonary circuit to the lungs and a systemic system to distribute the oxygenated blood to the rest of the body.

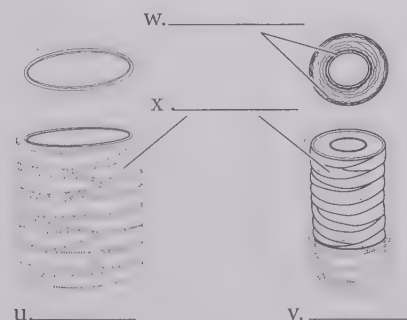
Arteries are thick-walled vessels because they have a substantial layer of smooth muscle and elastic fibers, which allows for expansion of vessels during heart contractions and modulation of blood pressure by constricting or dilating the arteries. Arterial distribution of blood occurs through the **pulmonary trunk** and **aorta**—the great vessels that leave the heart. The pulmonary trunk divides into right and left **pulmonary arteries**; each further branches to provide blood to each of the lobes of the lung. The **aorta** divides as it arches to the left shortly after exiting the heart; the **ascending aorta** supplies blood to regions anterior to the heart, and the **descending aorta** serves tissues and organs posterior to the heart.

Names of arteries are usually related to the organs and tissues they supply or to their location in the body. Although it is occasionally difficult to discern that connection, learn each artery's name along with the parts of the body supplied by it as you color each vessel. Label the structures in the diagrams—following convention, color arteries red. The exception is to color the pulmonary arteries blue (because they carry deoxygenated blood away from the heart).



Answer Key:

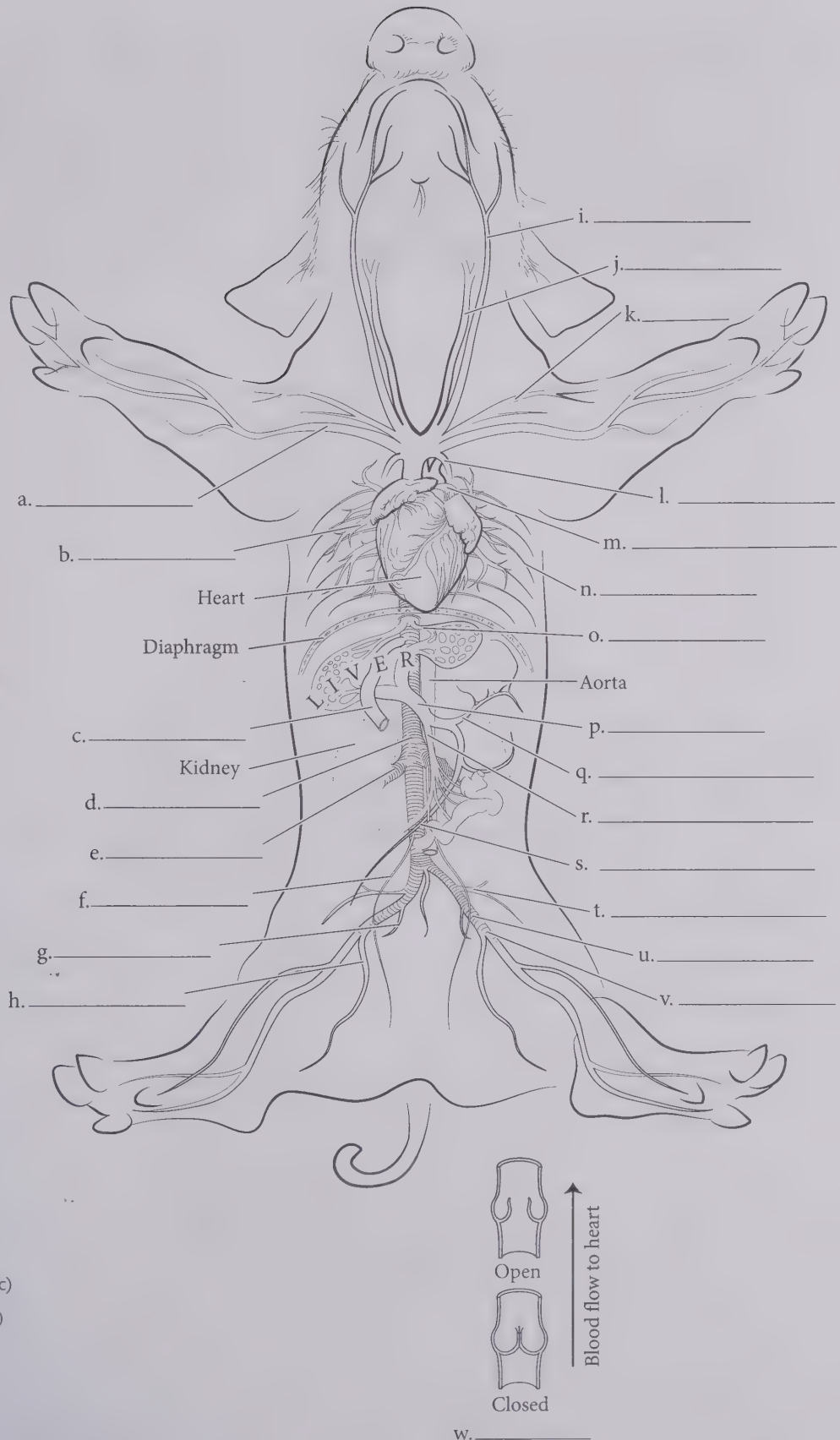
- | | | |
|------------------------|----------------------|-------------------|
| a. Thyrocervical trunk | i. Median sacral | q. Genital |
| b. Internal thoracic | j. Common carotid | r. External iliac |
| c. Intercostal | k. Subclavian | s. Internal iliac |
| d. Cranial mesenteric | l. Pulmonary | t. Femoral |
| e. Renal | m. Heart | u. Vein |
| f. Umbilical (cut) | n. Aorta | v. Artery |
| g. Circumflex iliac | o. Celiac | w. Elastic fibers |
| h. Deep femoral | p. Caudal mesenteric | x. Smooth muscle |



VENOUS SYSTEM

The walls of **veins** are thinner than those of arteries, and they have little smooth muscle or elastic fibers. They can expand to accept blood but do not actively contract again. However, veins have one-way valves to prevent backflow. Veins carry blood back to the heart; **pulmonary veins** (two from each side) enter the heart directly as they return blood which has been oxygenated in the lungs. The veins of the systemic circulation empty into the **cranial or caudal vena cava**. The two venae cava enter the right atrium independently.

Again, the names of veins are usually related to their location and function. As you color each vein, learn its name along with the parts of the body that it drains. Label the structures in the diagram—again, following convention, color veins blue. The exception is to color the pulmonary veins red (because the blood here is oxygenated).



Answer Key:

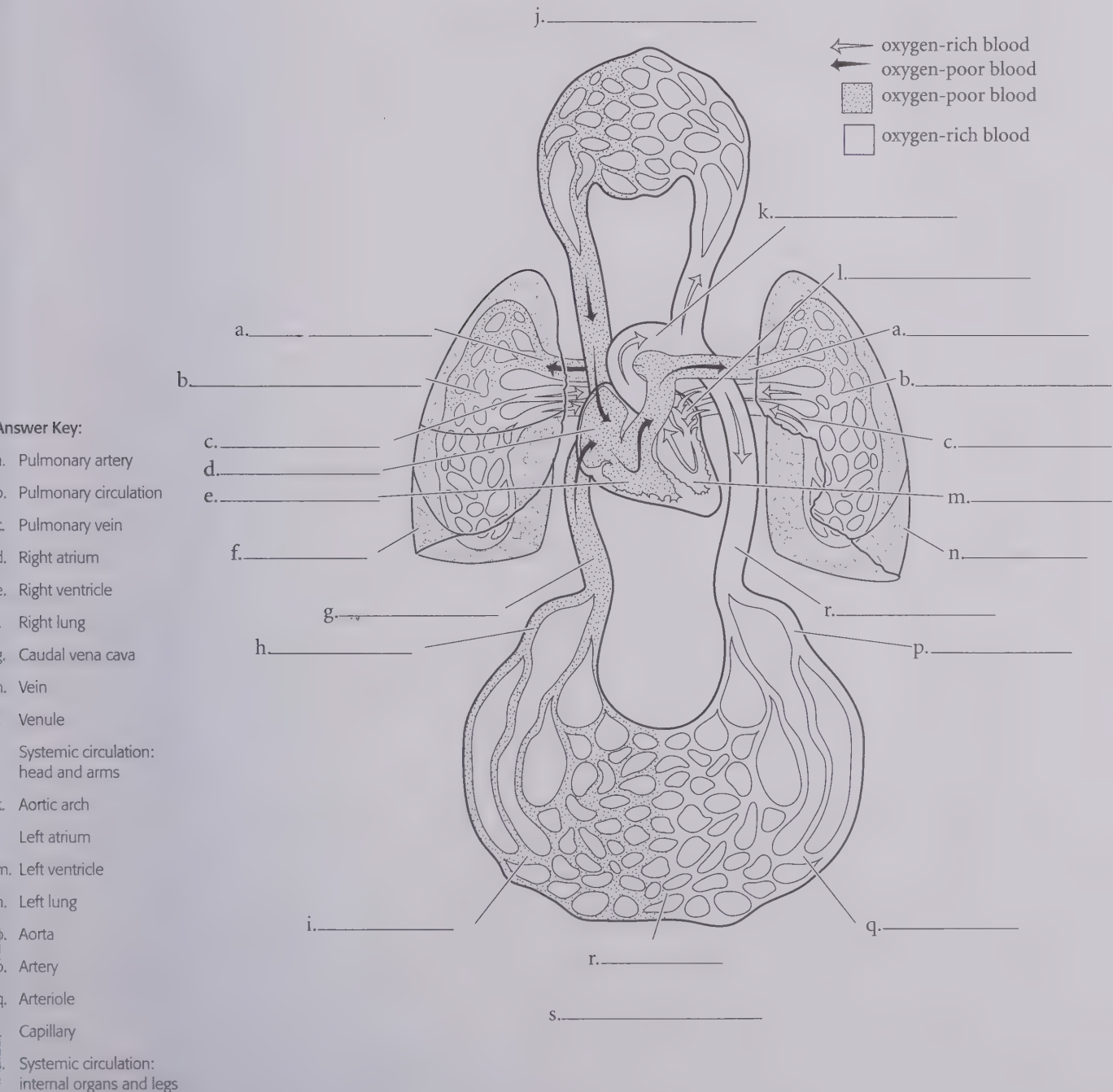
- Right subclavian
- Pulmonary
- Umbilical (cut)
- Caudal vena cava (Inferior vena cava)
- Right renal
- Genital
- Internal iliac
- Deep femoral
- External jugular
- Internal jugular
- Cephalic
- Internal thoracic
- Pulmonary trunk
- Intercostal
- Hepatic
- Portal
- Gastro-splenic
- Cranial mesenteric (Superior mesenteric)
- Caudal mesenteric (Inferior mesenteric)
- Circumflex iliac
- External iliac
- Femoral
- Venous valve

ADULT CIRCULATION

Like all mammals, pigs have a double circulation—a **pulmonary circulation** that carries blood between the heart and the lungs, and a **systemic circulation** between the heart and all other tissues of the body. In the pulmonary circulation, the right ventricle pumps blood to the lungs through the pulmonary trunk which divides to form left and right pulmonary arteries; pulmonary veins return oxygenated blood to the left **atrium** of the heart. In the systemic circulation, the left ventricle pumps blood through the aorta, from which exit major arteries serving all parts of the pig's body. The arteries divide into smaller vessels called **arterioles** and eventually feed capillaries. In the capillaries, oxygen and nutrients are supplied to the tissues, and waste products are removed. The blood then returns to the right atrium as capillaries feed into **venules**, combining

to form veins which join to form the vena cava before they enter the heart. Just as the pulmonary circulation divides to the left and right lungs, the systemic circulation splits shortly after leaving the heart to supply both the anterior and posterior regions of the organism.

Follow the blood flow as you color the oxygenated areas red and the deoxygenated areas blue in the diagram. At each point, be sure you recognize whether the blood is oxygenated or deoxygenated, which circulation you are part of, and whether the vessel is an artery or vein. This is also a good time to recognize the advantages of a four-chambered heart which can keep both circulations going simultaneously, while keeping oxygenated and deoxygenated blood separate.

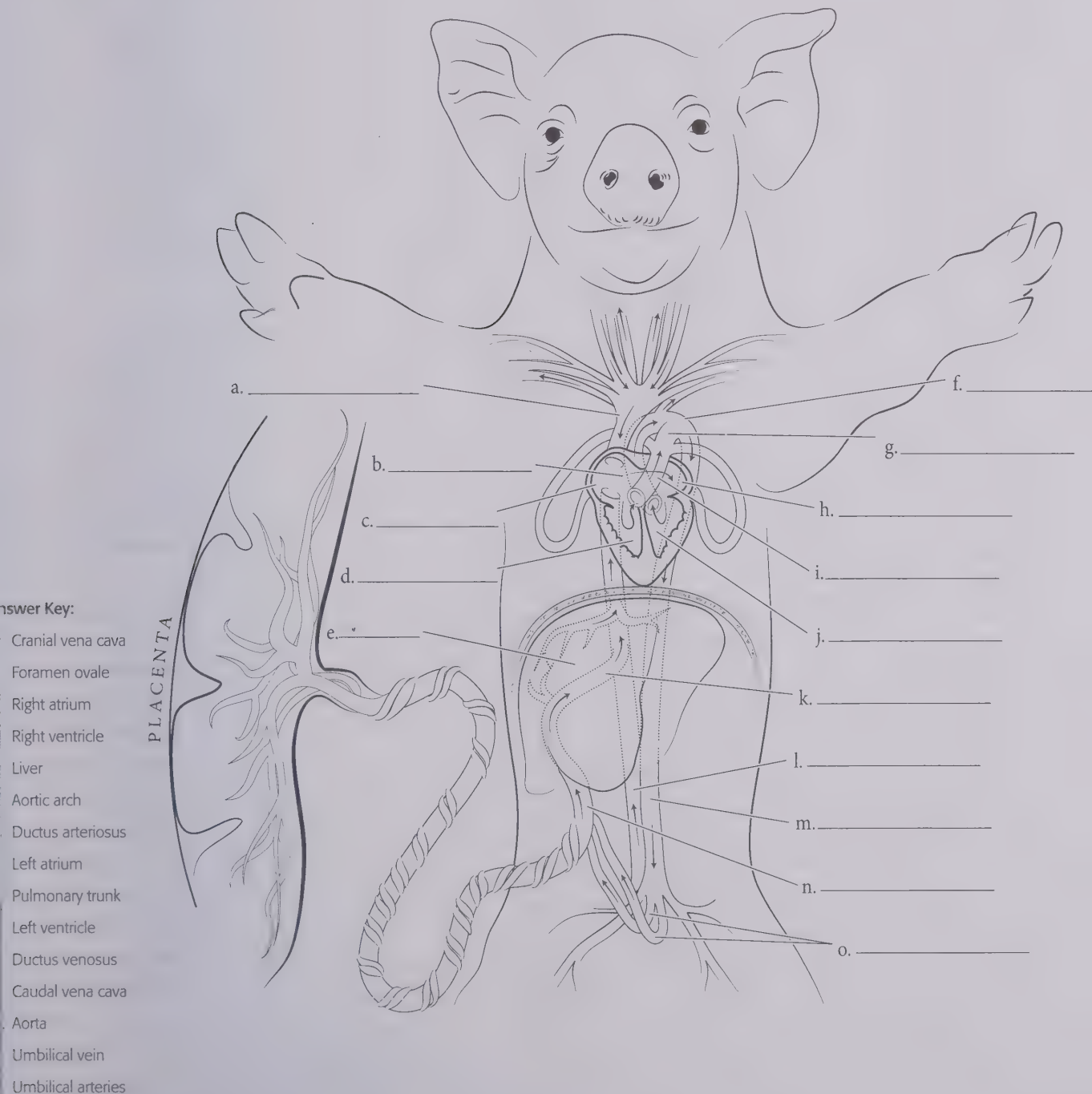


FETAL CIRCULATION

Since a fetal pig has not yet breathed air on its own, its blood is oxygenated externally in the placenta rather than in the lungs; several fetal adaptations make distribution of oxygen and nutrients more efficient. These “shortcuts” will close shortly after birth to allow blood to flow to the lungs for gas exchange.

The umbilical arteries bring fetal blood to capillaries of the placenta where gases and nutrients can diffuse between fetal and maternal blood. Oxygenated and nutrient-rich blood then returns to the fetus through the umbilical vein, which joins the hepatic portal vein and enters the liver. However, much of the blood instead goes through a “bypass” called the **ductus venosus**, from the umbilical vein directly into the caudal

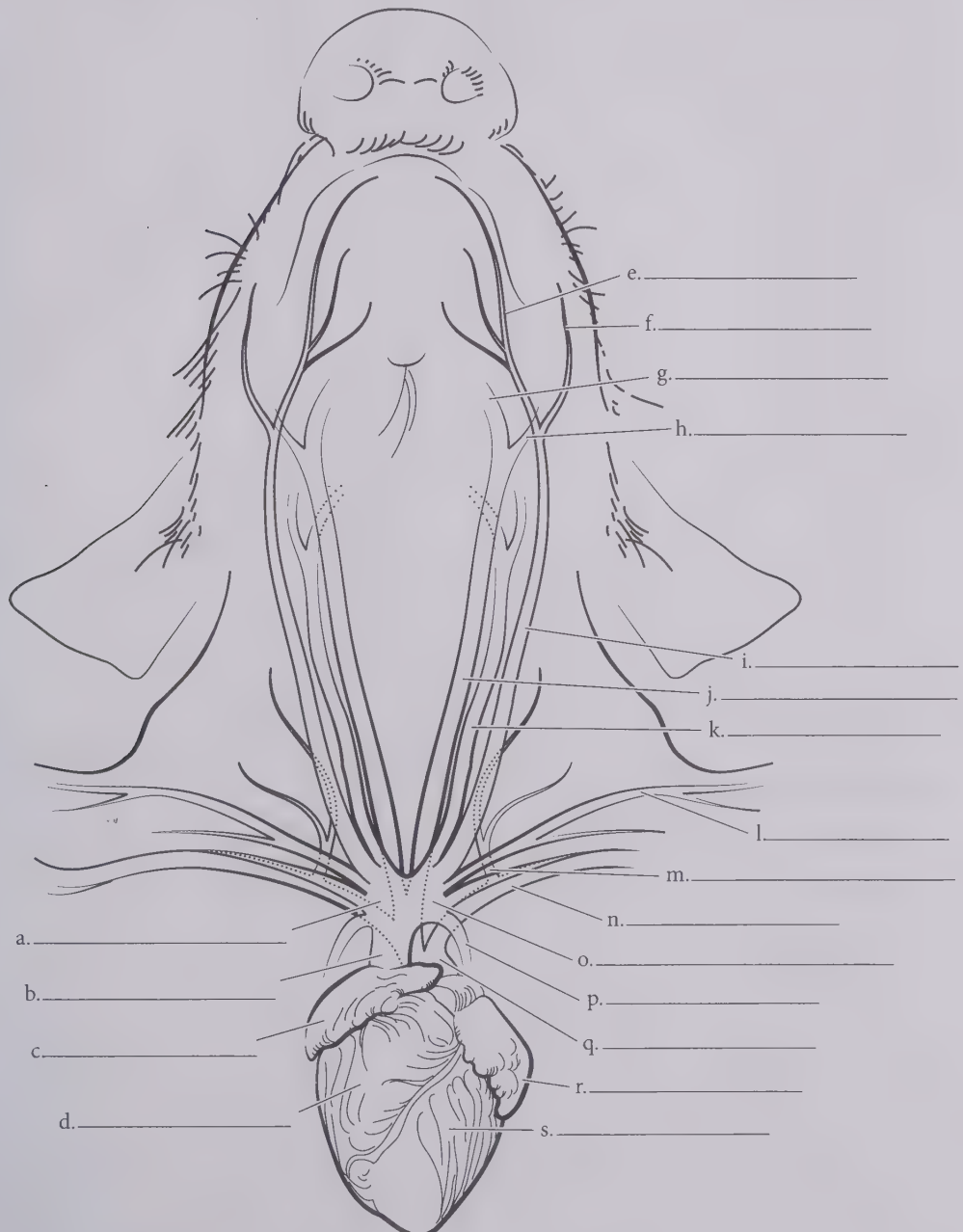
vena cava—and proceeds to the heart for distribution to the rest of the body. Reaching the right atrium, this blood would normally be destined for the lungs, but in the fetus, a hole called the **foramen ovale** between the two atria allows the blood from the umbilical vein to pass largely from the vena cava through the right atrium and into the left atrium, from which it is pumped into the systemic circulation. A final fetal adaptation is the **ductus arteriosus**, which allows oxygen-poor blood to largely bypass the lungs. Instead, much of the blood entering the pulmonary trunk is shunted over to the aorta, shortly after the arteries to the head and neck have branched off, allowing oxygen-poor blood to mix with nutrient-rich blood destined for the posterior half of the body, including



VESSELS OF HEAD AND NECK

Several arteries branch shortly after the aorta leaves the left ventricle of the heart; they provide circulation to the head and neck area. As the aorta arches to the left, the **brachiocephalic trunk** and the left **subclavian artery** branch off. The brachiocephalic trunk soon divides to form the right subclavian and a pair of **common carotid arteries**. Paralleling these major arteries are veins that return blood from the head and neck. The cranial vena cava carries this blood into the right ventricle. Its

tributaries are the left and right **brachiocephalic veins** which, in turn, are formed by the union of **subclavian** and **jugular veins**. The names for many of these arteries and veins may be remembered by identifying the location referred to in the name; for example, the brachiocephalic serves both the forelimb and the head (brachium is arm; cephalic refers to head), and the subclavian would lie below the clavicle in humans (the name is the same even though the pig does not have a clavicle).



Answer Key:

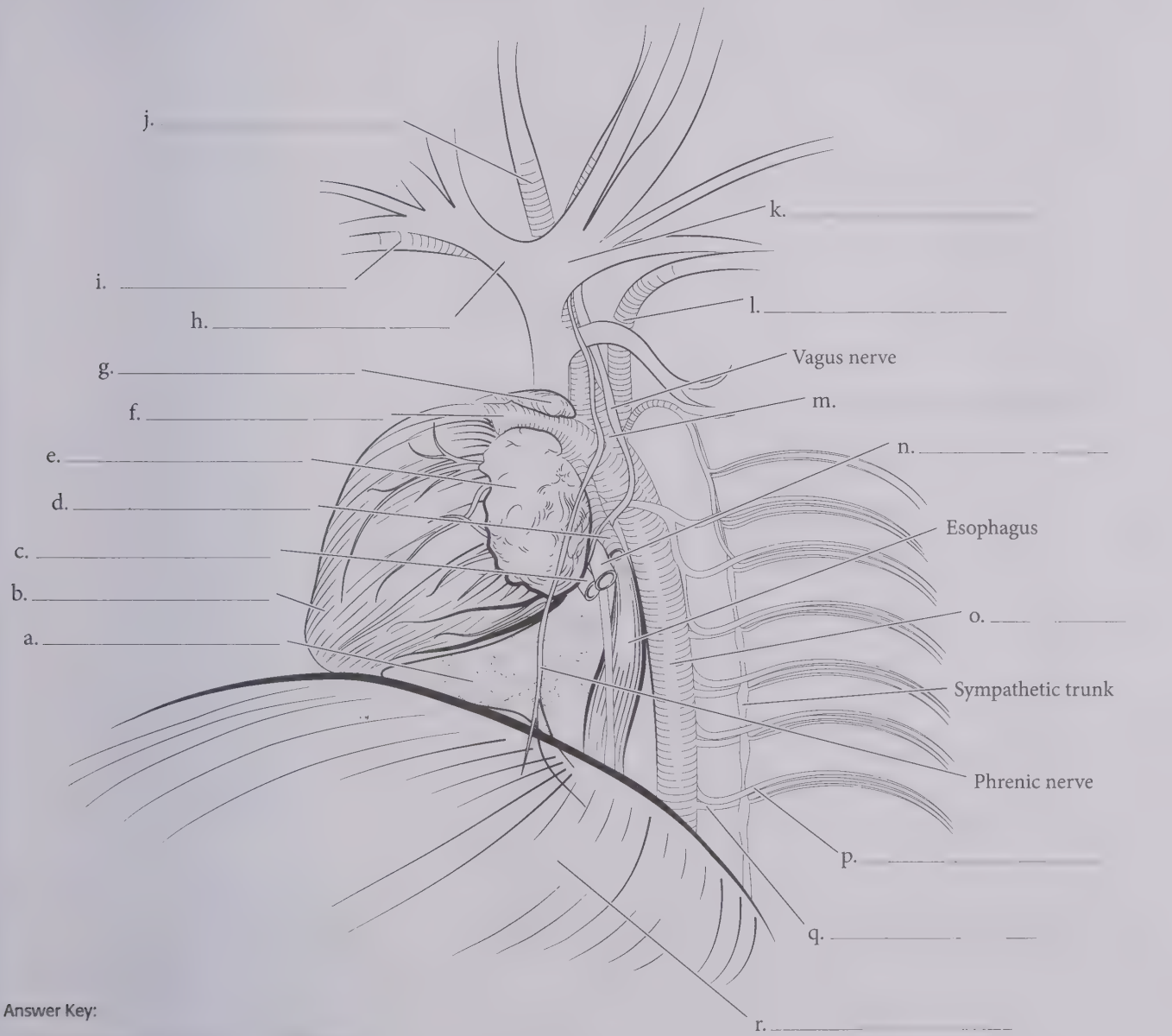
- a. Right brachiocephalic vein
- b. Cranial vena cava
(Superior vena cava)
- c. Right atrium
- d. Right ventricle
- e. Lingual vein
- f. External maxillary vein
- g. Internal carotid artery
- h. External carotid artery
- i. External jugular vein
- j. Common carotid artery
- k. Internal jugular vein
- l. Cephalic vein
- m. Thyrocervical trunk
- n. Left subclavian artery
- o. Left brachiocephalic vein
- p. Internal mammary vein
- q. Aortic arch
- r. Left atrium
- s. Left ventricle

LATERAL HEART AND GREAT VESSELS

The circulatory system of the pig includes a four-chambered heart capable of supplying blood from the heart to the lungs as well as the systemic circulation. The heart is located in the thoracic cavity, inside a tough membrane called the **pericardium** which is filled with fluid and protects the heart from injury. The esophagus passes through the thoracic cavity dorsal to the heart, the lungs surround it on either side, and the diaphragm provides the caudal wall of the cavity.

Looking here from the left side of the heart, the left atrium and ventricle are closest, with the left atrium looking like a cap placed atop the

ventricle. The most obvious vessel on the ventral side is the pulmonary trunk, emerging from the right ventricle and passing over the site where the aorta leaves the left ventricle. The two appear to merge together in the fetus, at the site of the ductus arteriosus. After passing this point, the aorta turns caudally and extends the length of the trunk along the dorsal wall of the abdomen. Arteries branch off this descending aorta into the regions between ribs (**intercostals**) and supply abdominal organs as well as the hind limbs.



Answer Key:

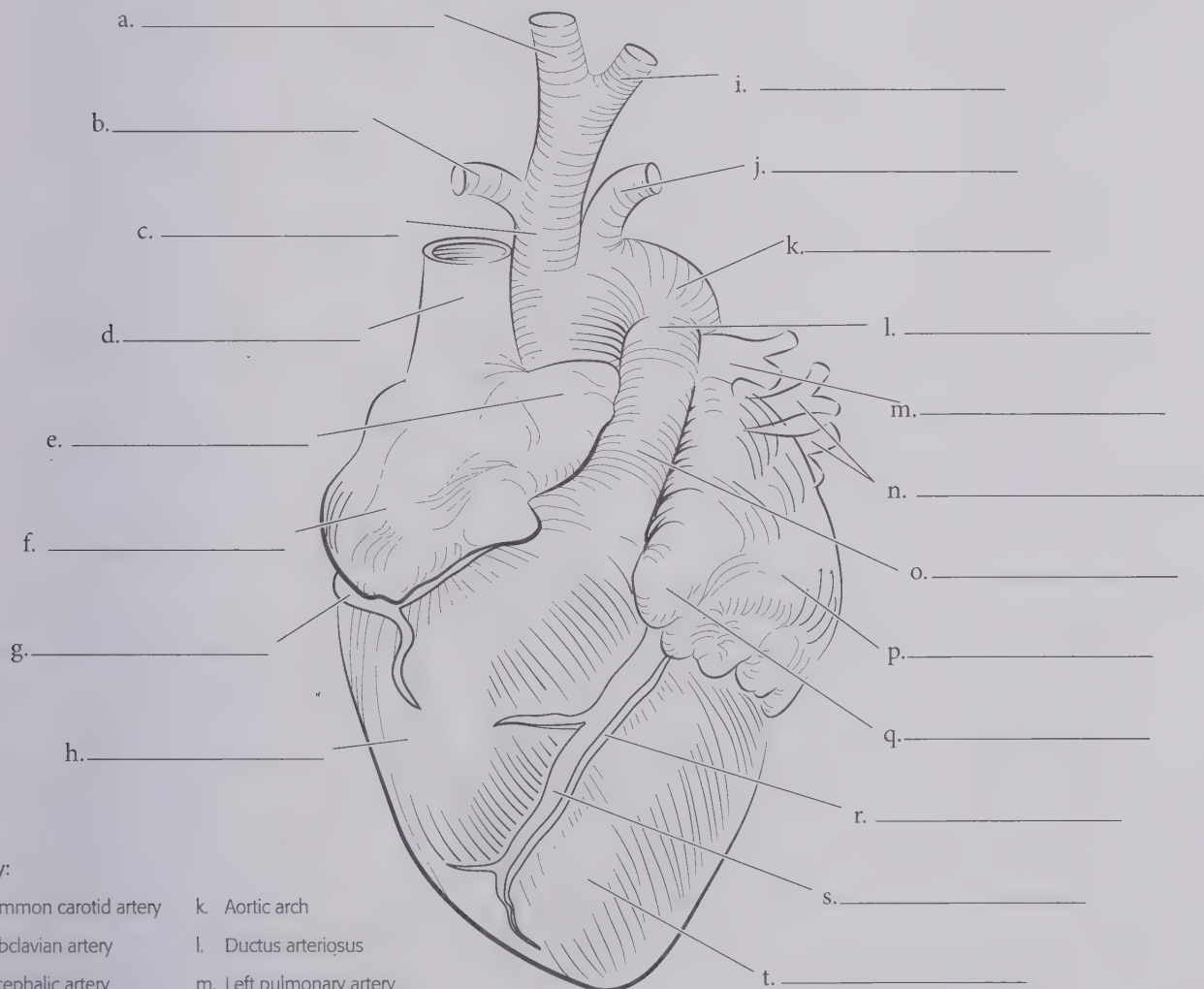
- | | | |
|---------------------------------|--------------------------------|-----------------------|
| a. Accessory lobe of right lung | g. Right atrium | m. Ductus arteriosus |
| b. Heart | h. Right brachiocephalic vein | n. Left bronchus |
| c. Left pulmonary vein | i. Right subclavian artery | o. Aorta |
| d. Left pulmonary artery | j. Right common carotid artery | p. Intercostal vein |
| e. Left atrium | k. Left brachiocephalic vein | q. Intercostal artery |
| f. Pulmonary trunk | l. Left subclavian artery | r. Diaphragm |

VENTRAL HEART

Seen from the ventral aspect, the left atrium and ventricle are on the right, the right atrium and ventricle are on the left. The apex or base points caudally; the great vessels emerge at the cranial end of the heart. **Coronary arteries** are obvious on the surface of the heart; they emerge from the base of the aorta too deep for the source to be visible externally. The large **left coronary vein** is also seen on this aspect. The pulmonary trunk is the most obvious great vessel; the aorta arises from the left ventricle behind the pulmonary trunk, divides to give rise to the brachiocephalic and left subclavian arteries, and arches to the left. As the aorta passes over the pulmonary trunk in the fetus, the ductus arteriosus connects the two vessels to shunt more of the blood away from the non-functional lungs and into the aorta. From this aspect, the cranial vena cava is evident as it enters the right atrium; the caudal vena cava enters

the same atrium on the dorsal, caudal side. This deoxygenated blood goes from the right atrium, into the right ventricle, and out the pulmonary trunk. Distal to the ductus arteriosus, the pulmonary trunk divides to form the left and right pulmonary arteries to supply the lungs. Blood returning from the lungs through the pulmonary veins enters the left atrium, on its way to the left ventricle and the aorta.

Label all vessels entering or emerging from the heart; color them appropriately according to the oxygenation status of the blood. To do this properly, you will need to know the role each plays in the systemic or pulmonary circulation, so it is a good time to test yourself on your ability to trace the path of blood through both circulations, and through the heart.

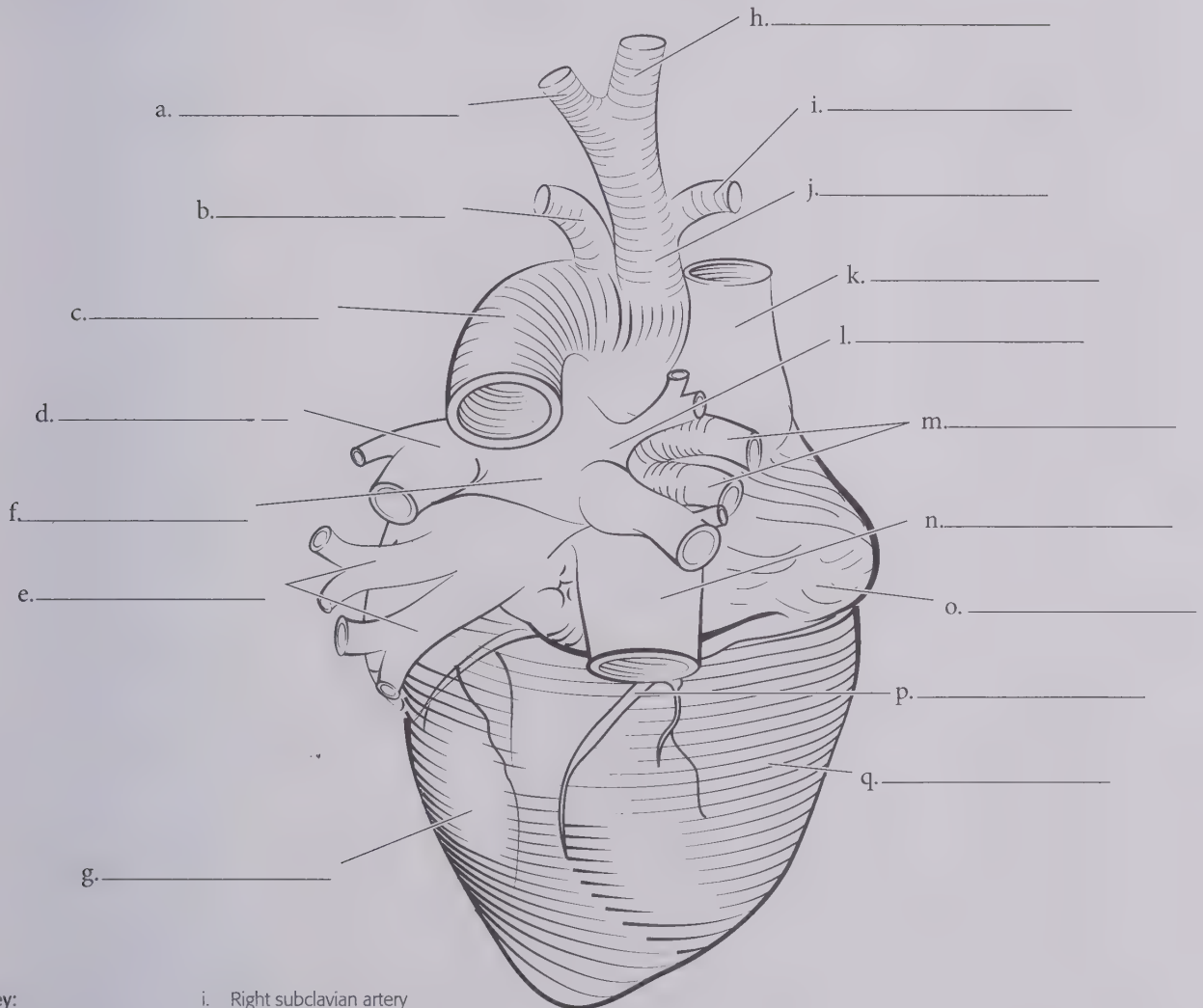


Answer Key:

- | | |
|--------------------------------|--------------------------|
| a. Right common carotid artery | k. Aortic arch |
| b. Right subclavian artery | l. Ductus arteriosus |
| c. Brachiocephalic artery | m. Left pulmonary artery |
| d. Cranial vena cava | n. Left pulmonary veins |
| e. Right auricle | o. Pulmonary trunk |
| f. Right atrium | p. Left atrium |
| g. Right coronary artery | q. Left auricle |
| h. Right ventricle | r. Left coronary artery |
| i. Left common carotid artery | s. Great cardiac vein |
| j. Left subclavian artery | t. Left ventricle |

DORSAL HEART

On the dorsal aspect of the heart, the two pulmonary arteries are clearly visible below the aortic arch; each divides to provide blood flow to the individual lobes. Below them can be seen two pulmonary veins on each side as they enter the left atrium to return oxygenated blood from the lungs. Entering the right atrium are two large vessels—the cranial vena cava at the top, and the caudal vena cava below. They carry deoxygenated blood from the anterior and posterior parts of the systemic circulation into the right side of the heart to be pumped out the pulmonary trunk.



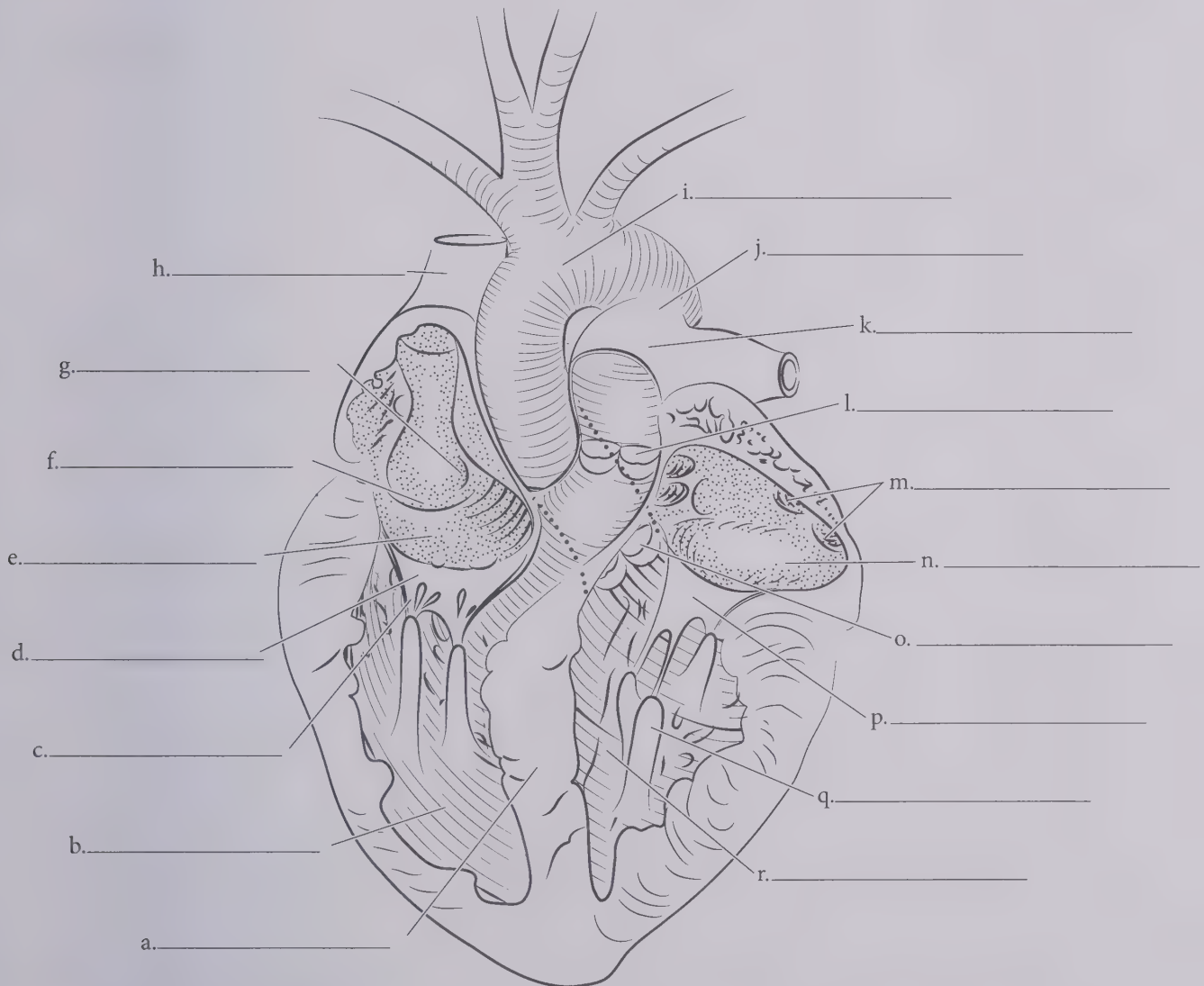
Answer Key:

- | | |
|--------------------------------|----------------------------|
| a. Left common carotid artery | i. Right subclavian artery |
| b. Left subclavian artery | j. Brachiocephalic artery |
| c. Aortic arch | k. Cranial vena cava |
| d. Left pulmonary artery | l. Right pulmonary artery |
| e. Left pulmonary veins | m. Right pulmonary veins |
| f. Left atrium | n. Caudal vena cava |
| g. Left ventricle | o. Right atrium |
| h. Right common carotid artery | p. Right coronary artery |
| | q. Right ventricle |

FRONTAL PLANE OF HEART

Looking at the inside of the heart from the ventral view, all four chambers of the heart are visible. Color the structures in the same order as the blood flows to each on its route through the heart. Two kinds of valves keep the blood from flowing backwards. The **atrioventricular valves** open when the ventricle relaxes, allowing blood to flow from the atrium into the ventricle. These valves are connected via the **chordae tendinae** to papillary muscles which are stimulated to contract along with the adjacent ventricular muscle; this action pulls the valve flaps closed, preventing blood from backing up into the atrium when the ventricle contracts. On the right side, this valve is called the **tricuspid**, on the left it is called the **bicuspid** or sometimes the mitral valve, especially in humans. The other heart valves are **semilunar valves**, placed between the ventricles and the pulmonary trunk or the aorta; these cup-like valves close as they fill with blood when it begins to back up as the ventricle relaxes.

Atrial walls are quite thin as they only need to create enough force to empty the atrium into the ventricle when the atrioventricular valve opens. The interatrial septum is perforated by the foramen ovale in the fetus, allowing placental blood entering the right atrium through the caudal vena cava to largely exit to the left atrium for distribution throughout the systemic circulation. Note the interventricular septum between the two ventricles, and the thick ventricular walls which can contract with enough force to push the blood out of the heart, through the arteries, capillaries, and veins, and back to the heart again. The left ventricular wall is much thicker than the right since more force is needed to get blood throughout the systemic circulation than the shorter passage through the lungs.



Answer Key:

- a. Interventricular septum
- b. Right ventricle
- c. Chordae tendinae
- d. Right atrioventricular (tricuspid) valve

e. Right atrium

f. Caudal vena cava aperture

g. Foramen ovale

h. Cranial vena cava

i. Aortic arch

j. Ductus arteriosus

k. Pulmonary trunk

l. Pulmonary semilunar valve

m. Pulmonary vein apertures

n. Left atrium

o. Aortic semilunar valve

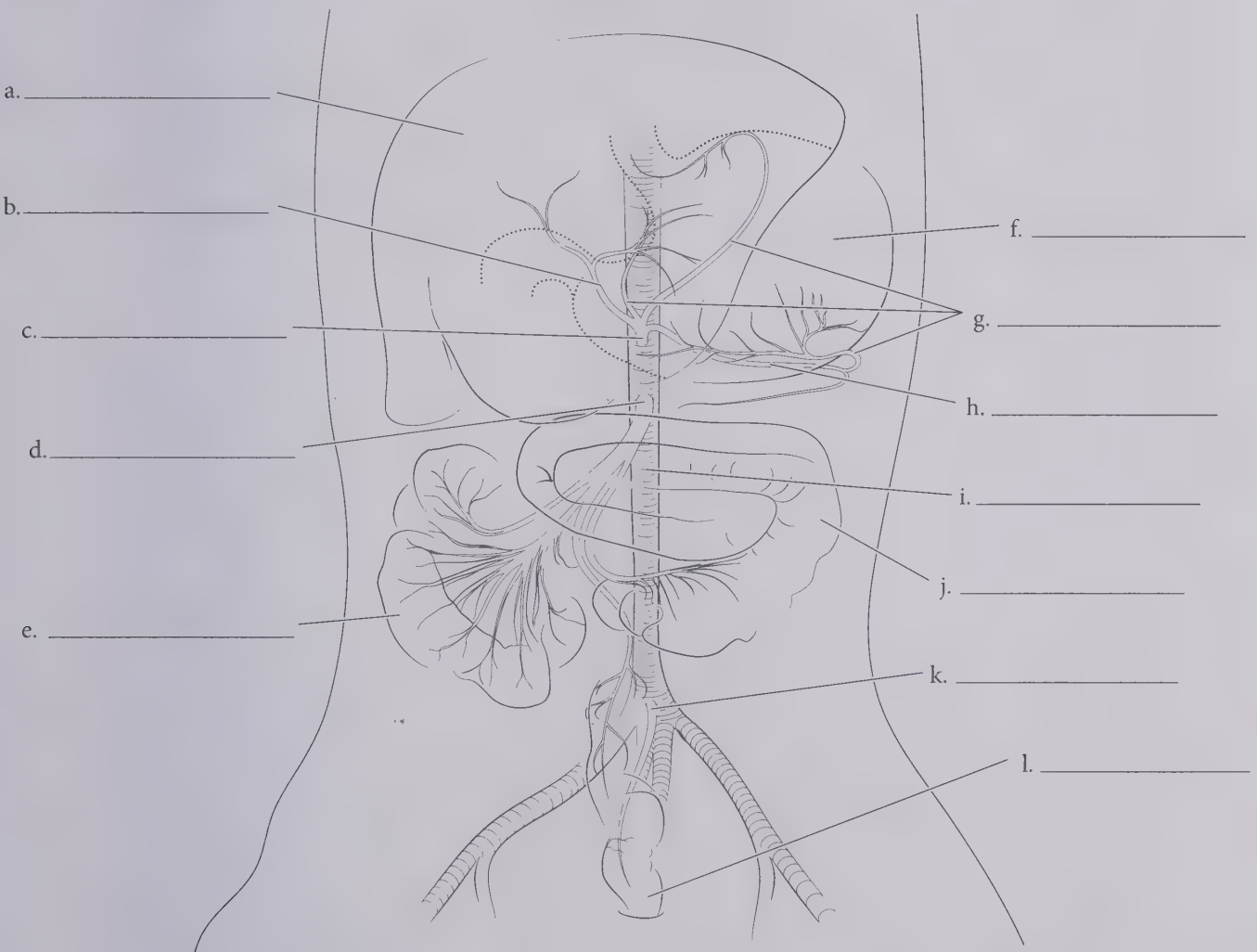
p. Left atrioventricular (bicuspid, mitral) valve

q. Papillary muscle

r. Left ventricle

VENTRAL ARTERIES OF DIGESTIVE ORGANS

Several unpaired vessels arising off the abdominal aorta provide oxygenated blood to organs of the digestive system. The **celiac trunk** divides into branches named for the organs they supply: the hepatic artery to the liver, the gastric arteries to the stomach, and the **splenic artery** to the spleen. The **cranial mesenteric artery** branches into numerous arteries passing throughout the mesentery to provide blood along the entire length of the small intestine, where nutrients are being absorbed. The **caudal mesenteric artery** supplies blood to much of the colon. As you color each artery, name the organ that it supplies and also color the digestive organs, using the same colors you used previously for each organ.



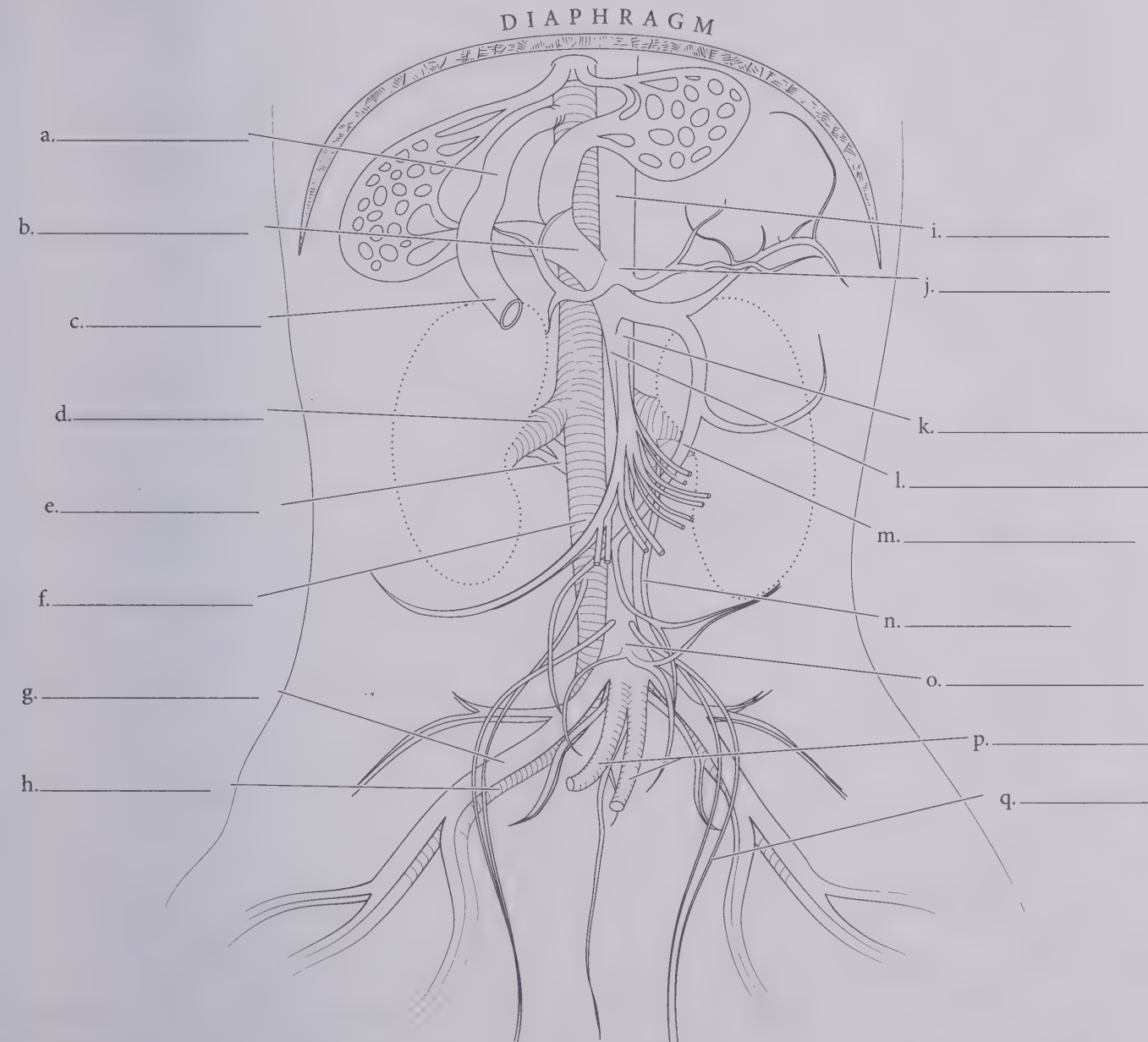
Answer Key:

- | | |
|------------------------------|-----------------------------|
| a. Liver | g. Gastric arteries |
| b. Common hepatic artery | h. Splenic artery |
| c. Celiac trunk | i. Aorta |
| d. Cranial mesenteric artery | j. Spiral colon |
| e. Small intestine | k. Caudal mesenteric artery |
| f. Stomach | l. Rectum |

VENTRAL ABDOMINAL AORTA AND CAUDAL VENA CAVA

The abdominal organs are supplied with blood from the aorta as it passes dorsally through the abdominal region. In each organ, blood passes through capillaries, where oxygen and nutrient exchange takes place, and is collected again into veins. These veins then enter the caudal vena cava which carries the blood back to the right side of the heart. Select an artery; name it and color it (and its counterpart on the other side, if one of a pair); then, find the vein that completes the circuit back to the vena cava, name it, and color it.

A pair of **renal arteries** supplies the kidneys, while a pair of **renal veins** returns the blood to the vena cava. More caudally, **gonadal arteries** and **veins** supply the gonads, while the **external iliacs** supply the hind limbs. The abdominal aorta terminates in the fetus by dividing into a pair of umbilical arteries that supply blood to the placenta. Although the mesenteric arteries supply blood to digestive organs, mesenteric veins do not return the blood to the vena cava. Instead, they carry this nutrient-rich blood to the hepatic portal vein which carries it to the liver before it returns to the heart.



Answer Key:

- a. Ductus venosus
- b. Hepatic portal vein
- c. Umbilical vein
- d. Right renal vein

- e. Right renal artery
- f. Caudal vena cava
- g. External iliac artery
- h. External iliac vein
- i. Aorta

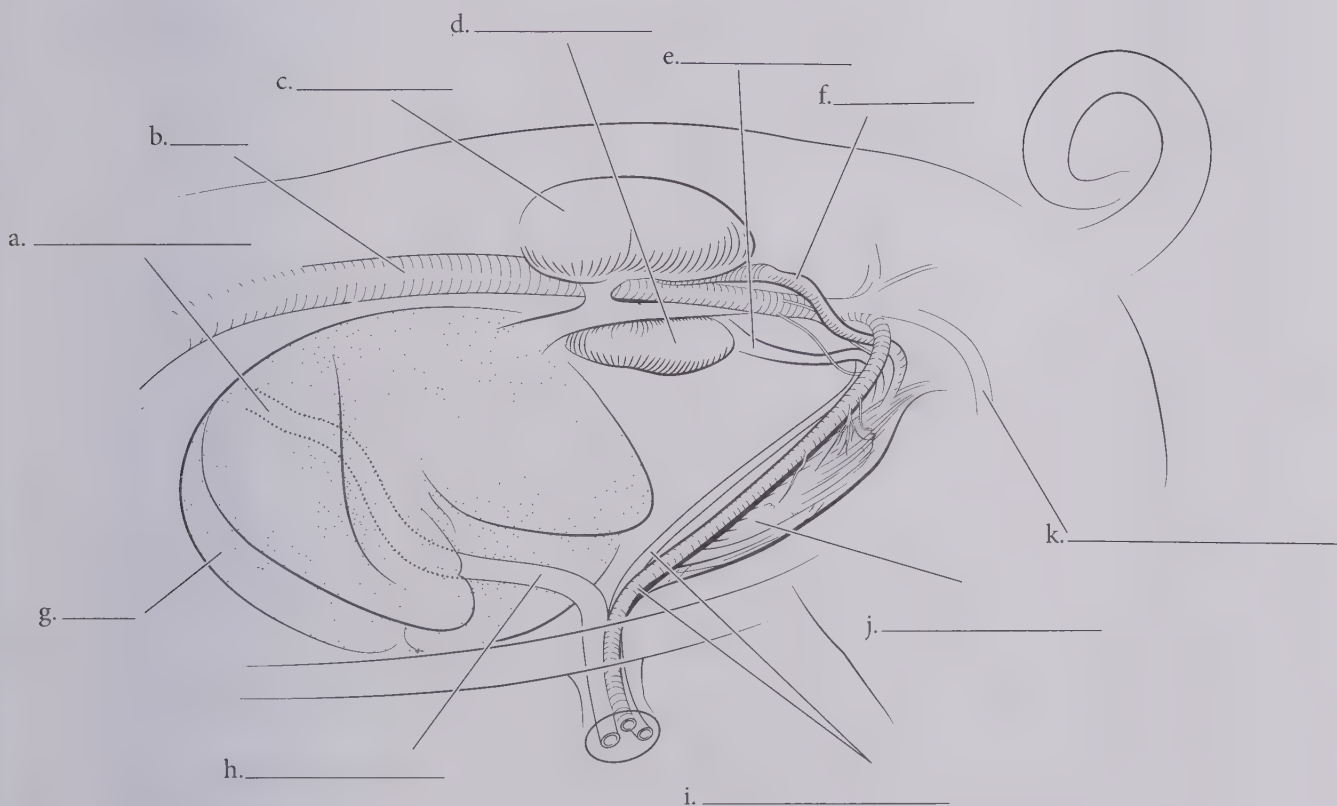
- j. Celiac trunk
- k. Cranial mesenteric artery
- l. Cranial mesenteric vein
- m. Caudal mesenteric vein
- n. Left gonadal vein

- o. Caudal mesenteric artery
- p. Umbilical arteries
- q. Left gonadal artery

UMBILICAL CORD, UMBILICAL VESSELS

In the fetus, a pair of umbilical arteries supplies blood from the aorta directly to the placenta. They are located alongside the **urinary bladder** and will close off after birth, but they remain in position as the ventral ligament of the bladder. Blood returning from the placenta through the single large umbilical vein is diverted through the ductus venosus to the vena cava to return directly to the heart.

Note the unusual situation in the fetus: Umbilical arteries carry deoxygenated blood that is low in nutrients, while the umbilical vein carries oxygenated and nutrient-rich blood. For this reason, in contrast to the other vessels of the systemic system, you should color the umbilical arteries in blue and the umbilical vein in red.



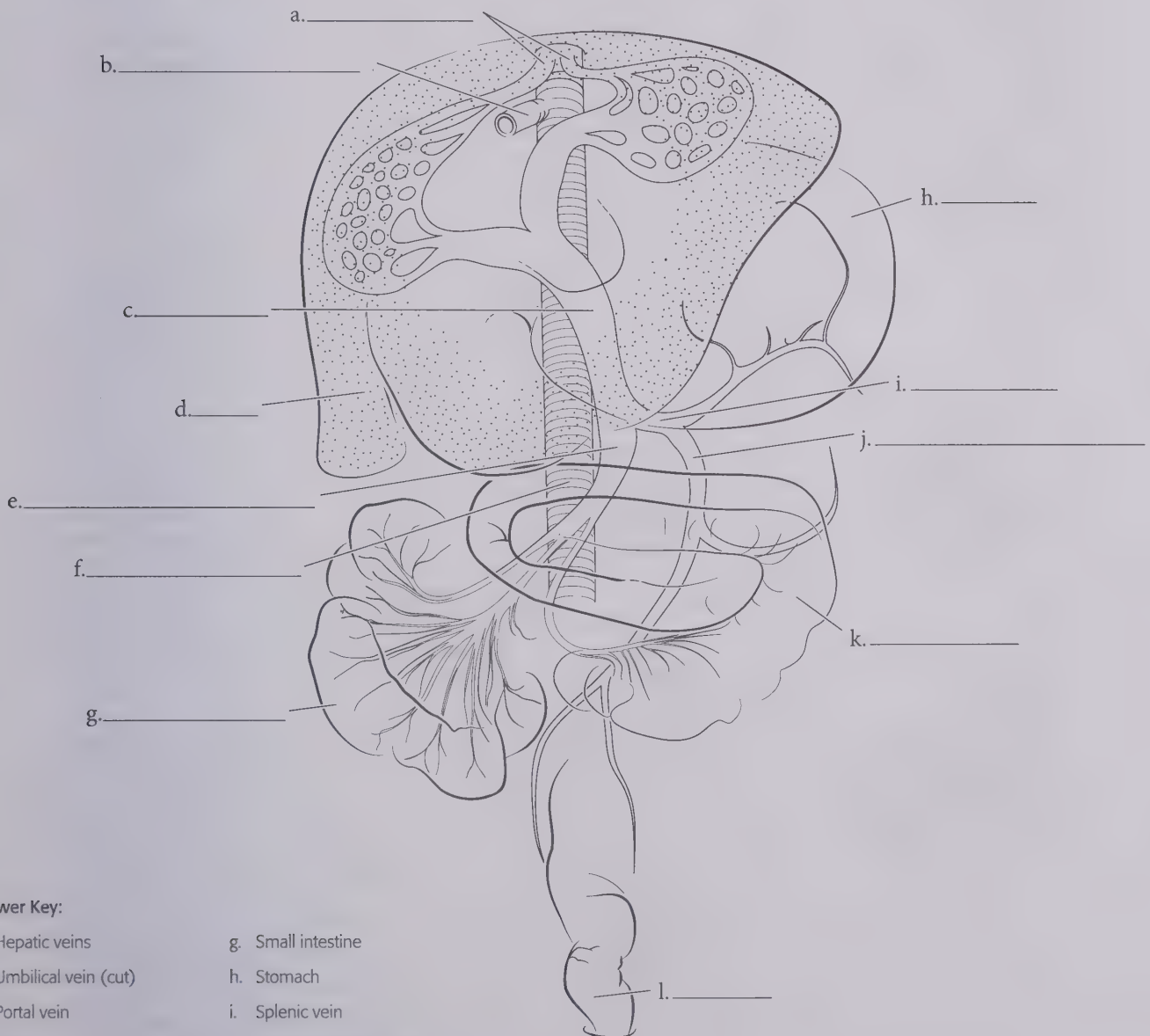
Answer Key:

- a. Ductus venosus
- b. Aorta
- c. Left kidney
- d. Right kidney
- e. Right ureter

- f. Left ureter
- g. Liver
- h. Umbilical vein
- i. Umbilical arteries
- j. Urinary bladder
- k. External iliac artery

PORTAL SYSTEM OF VEINS WITH ORGANS

In most of the body, blood flows from the heart, through arteries into capillaries, from capillaries into veins, and then back to the heart. Portal circulations represent an unusual local situation in which blood flows from one bed of capillaries through a vein and back into a second set of capillaries. In the hepatic portal system, blood drained from the capillaries in the intestines does not return to the vena cava, but rather is taken via the portal vein to another bed of capillaries in the liver. In the liver, the hepatocytes are exposed to the nutrient-rich blood where they are able to take up excess glucose and store it as glycogen, or filter out toxins and break them down. If the blood entering the liver is low in glucose, the hepatocytes can break down stored glycogen and secrete glucose into the blood to ensure a more even blood glucose level. The blood then is collected into the hepatic vein and enters the vena cava.



Answer Key:

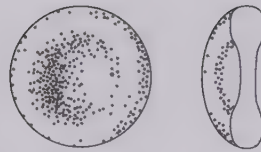
- | | |
|----------------------------|---------------------------|
| a. Hepatic veins | g. Small intestine |
| b. Umbilical vein (cut) | h. Stomach |
| c. Portal vein | i. Splenic vein |
| d. Liver | j. Caudal mesenteric vein |
| e. Cranial mesenteric vein | k. Spiral colon |
| f. Caudal vena cava | l. Rectum |

CIRCULATORY HISTOLOGY

Blood cells fall into three categories. Red blood cells, or **erythrocytes**, take up the largest part of the cellular volume of blood—about 5 million in each cubic millimeter. These small, biconcave, anuclear cells possess hemoglobin to bind, carry, and deliver oxygen; they also carry wastes such as carbon dioxide. Color the erythrocytes a pale pink to represent their appearance after the most common staining procedures. The smallest cell fragments are **platelets**, or thrombocytes, which function in blood clotting to prevent loss of blood after injury. There are more than 200,000 per cubic millimeter; color these a dark purple.

The remaining cells are **leukocytes**, or white blood cells, which are components of the immune system that usually number about 5,000 to 9,000 per cubic millimeter. Some are referred to as granular leukocytes because there are cytoplasmic granules that may be seen quite well using certain stains. **Eosinophils** (2%–5% of leukocytes) have pink or orange granules in a pale blue cytoplasm and a two-lobed nucleus that stains purple. Eosinophils participate in allergic reactions, fighting worm infections, and perform phagocytosis. **Basophils** (<1% of leukocytes) have intense, dark purple granules that often obscure the S-shaped nucleus, which also stains purple. Basophils are involved in release of histamine. The most numerous leukocytes are **neutrophils** (60%–70%); they have a 3–5 lobed nucleus that stains purple, a cytoplasm that stains light blue, and many granules that do not take up stain much at all. Neutrophils are phagocytic cells, involved in engulfing and digesting bacteria. Color the cytoplasm light blue and the nucleus purple.

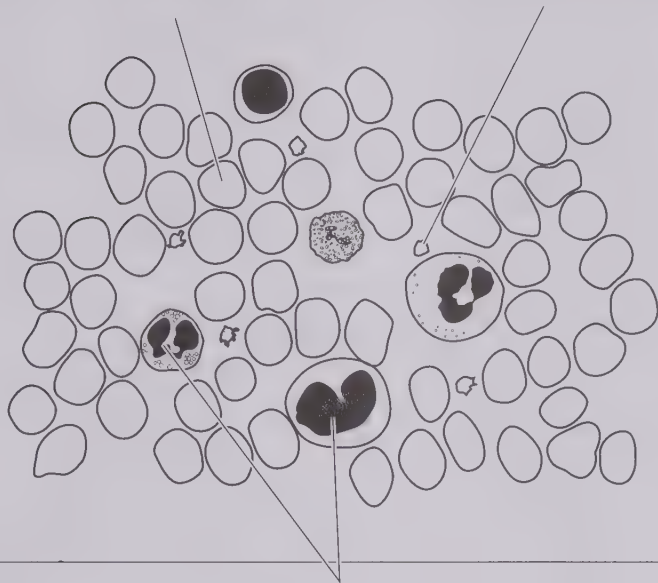
Agranular leukocytes fall into two categories. **Monocytes** are very large cells with a lobed nucleus that stains purple and pale blue cytoplasm; they make up about 5% of leukocytes. They migrate to areas of infection and appear to be the precursors of tissue macrophages that perform phagocytosis. **Lymphocytes** make up the remaining 20%–30% of leukocytes. They are usually relatively small cells, with a large purple nucleus and a small amount of light blue cytoplasm surrounding it. Lymphocytes come in two types—**B cells** are involved in antibody production, while **T cells** provide cell-mediated immunity or assist B cells in recognizing foreign materials.



a. _____



b. _____



c. _____

Granular



d. _____

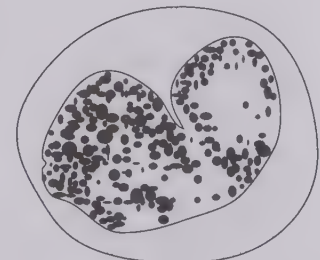
Agranular



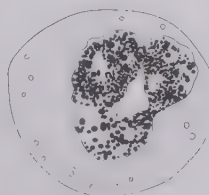
g. _____



e. _____



h. _____



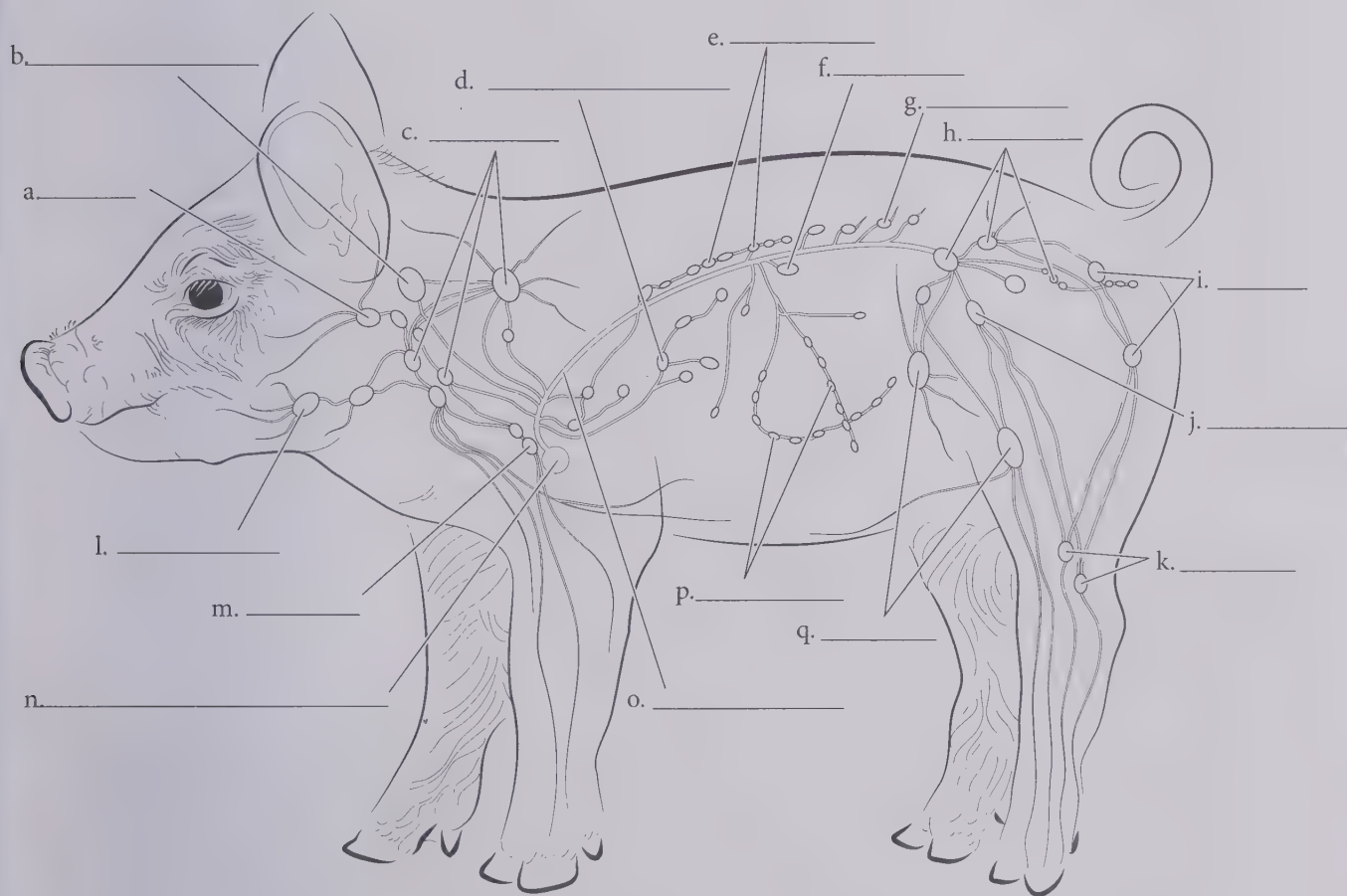
f. _____

Answer Key:

- a. Erythrocyte
- b. Thrombocyte
- c. Leukocytes
- d. Basophil
- e. Eosinophil
- f. Neutrophil
- g. Lymphocyte
- h. Monocyte

Although the circulatory system is a closed system, and blood always flows within vessels, some of the plasma fluid filters through the capillary walls and bathes the cells as interstitial fluid. While a small amount of this fluid filters back into the capillaries, the remainder is captured and returned to the circulation by the lymphatic system. The fluid enters **lymph capillaries**, which have highly permeable walls, and passes into progressively larger lymphatic vessels containing one-way valves to allow the fluid to move only toward the heart. The skeletal muscles through which the vessels pass exert a pressure that pushes the lymph along its way, and the largest vessels empty into veins on each side of the neck.

The lymphatic system plays a crucial role in immune reactions. Lymph fluid must pass through **lymph nodes** where microbial agents are filtered out. You can see here that lymph nodes are located where lymph collected from every part of the body must pass before returning to the heart. They are particularly prevalent in regions that drain lymph from the lungs, digestive tract, and skin—tissues with exposure to the external world and, therefore, with potential to be contaminated by bacteria and other foreign matter. Note that the names for many of the lymph nodes are derived from their location near various organs or structures in the body. As you color the lymph vessels and the nodes through which the lymph must pass, learn the names of the nodes while recognizing the structures for which they are named.



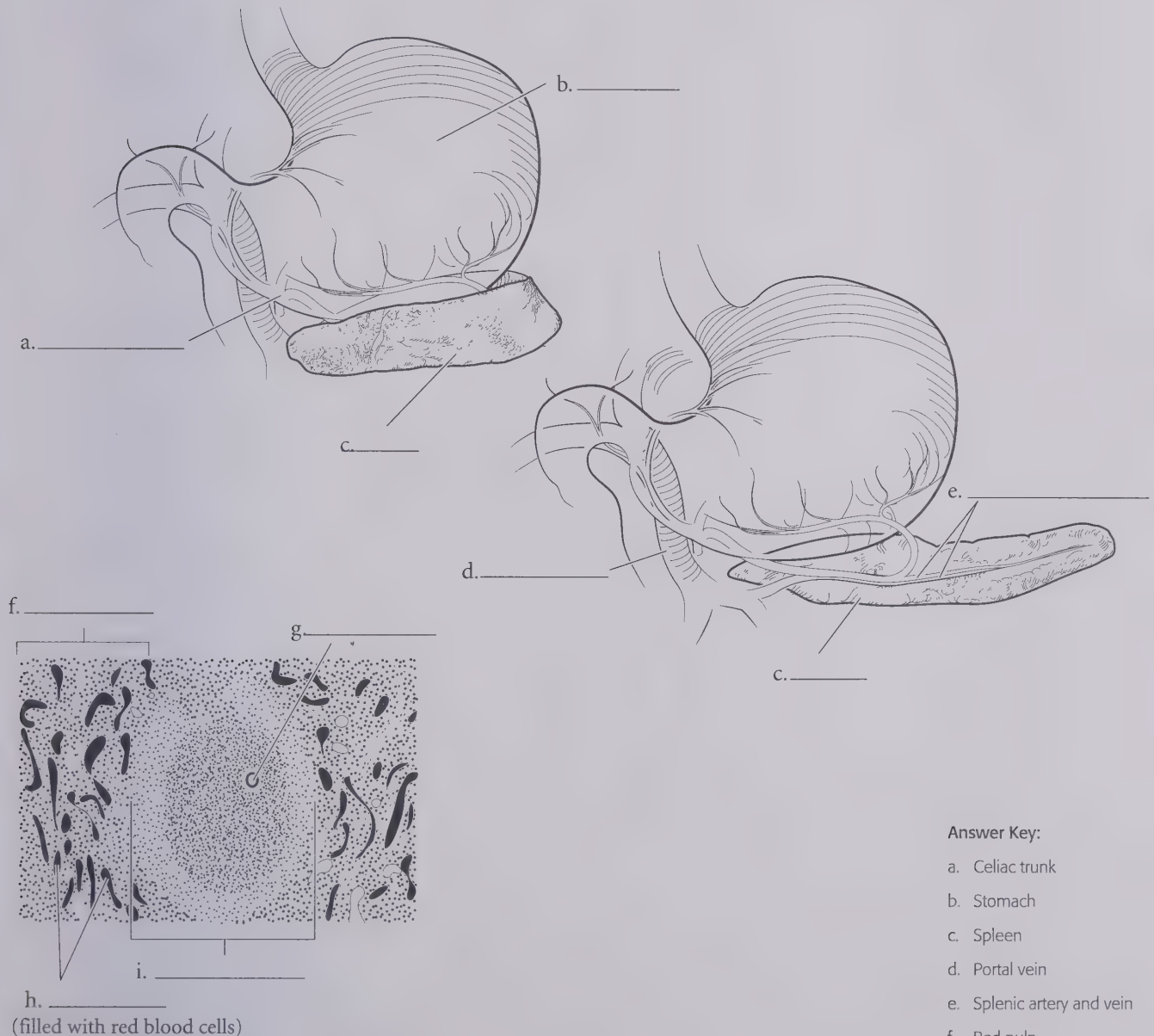
Answer Key:

- | | |
|---------------------|------------------------------|
| a. Parotid | i. Ischial |
| b. Retropharyngeal | j. Iliofemoral |
| c. Cervical | k. Popliteal |
| d. Tracheobronchial | l. Mandibular |
| e. Aortic | m. Axillary |
| f. Renal | n. Left brachiocephalic vein |
| g. Lumbar | o. Thoracic duct |
| h. Iliosacral | p. Mesenteric |
| | q. Inguinal |

SPLEEN WITH HISTOLOGY

Lymphatic organs in the pig include the **spleen** (shown here) and the **thymus**. The spleen is an elongated, reddish organ found ventral to the stomach, and it is the site of production for red blood cells as well as a location for filtering blood to remove damaged or old red blood cells and foreign material such as bacteria. The thymus is quite large in the fetus, extending through the neck region and into the thoracic cavity as well. It is a site for fetal red blood cell production, as well as a location where lymphocytes develop in order to provide cell-mediated immunity.

Histology of the spleen shows areas known as **red pulp** and **white pulp**. The red pulp is tissue that is filled with small vessels where blood (rich in erythrocytes) passes through. Old or damaged red cells are filtered out in this region, as well as bacteria or other foreign material. The white pulp consists of immune system cells arranged along arterioles. Macrophages and T cells recognize foreign material and respond to destroy it. B cells exposed to foreign antigens in the spleen will mature and begin producing antibodies.



Answer Key:

- a. Celiac trunk
- b. Stomach
- c. Spleen
- d. Portal vein
- e. Splenic artery and vein
- f. Red pulp
- g. Arteriole
- h. Sinuses
- i. White pulp

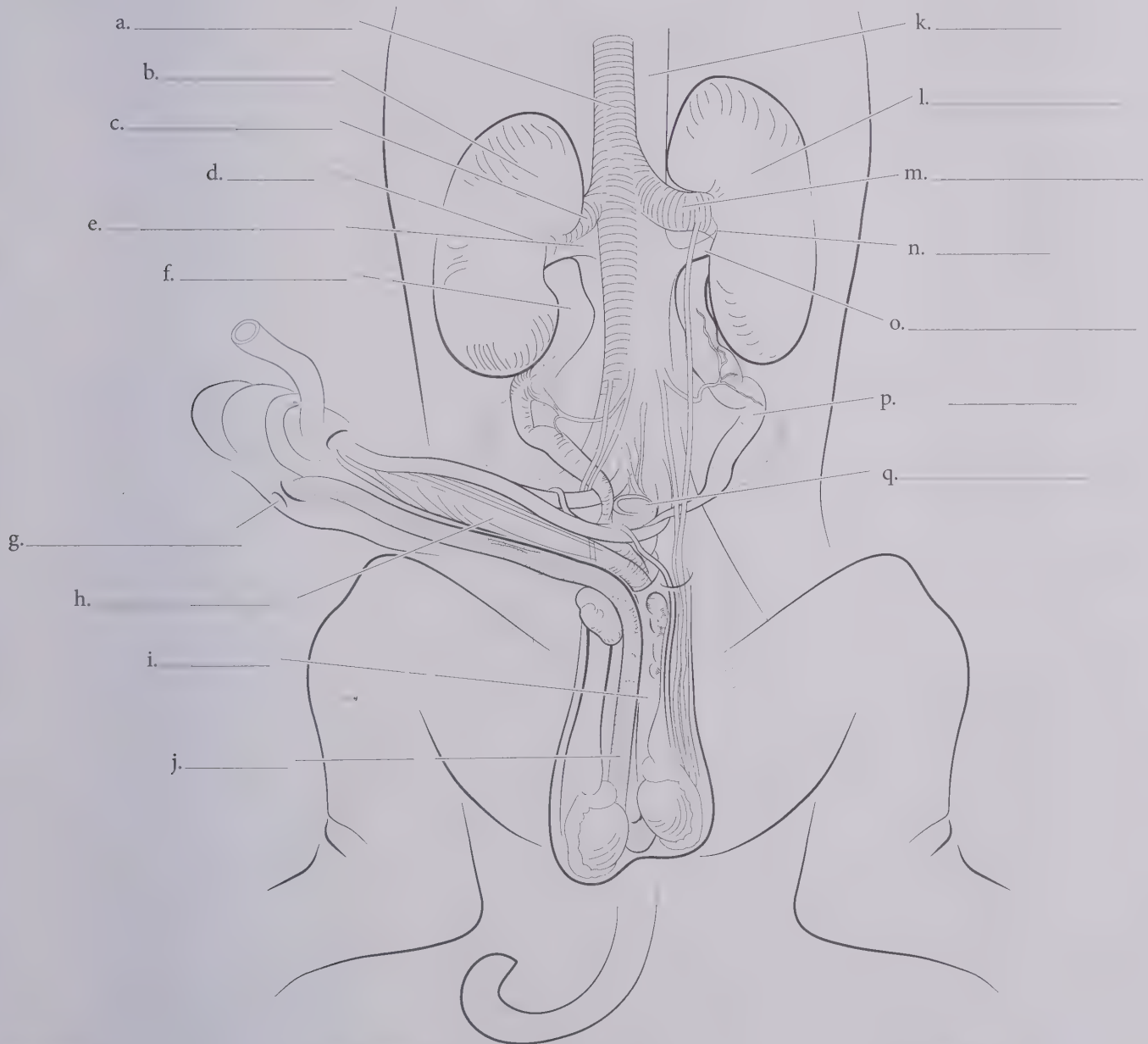
UROGENITAL SYSTEM, MALE

The urogenital system includes the kidneys and urinary bladder, as well as reproductive organs. As such, they differ significantly in male and female pigs. The reproductive organs have not matured enough in the fetal pigs to be functional, but all of the relevant organs have already formed.

The urinary system removes nitrogenous waste materials from the body. Note the pair of **kidneys** that are located in the dorsal abdominal wall, and the **ureters** that carry urine to the bladder which is located just

under the skin on the ventral side of the abdomen. Urine from the bladder is carried to the exterior through the **urethra**. In the male, the urethra passes through the penis and also carries the products from the male sex glands. The penis parallels the bladder and emerges through the urogenital opening just caudal to the umbilical cord.

Use a different color for organs of the reproductive system than you use to color the organs that are part of the urinary system.



Answer Key:

- a. Caudal vena cava
- b. Right kidney
- c. Right renal vein
- d. Hilum

- e. Right renal artery
- f. Right ureter
- g. Urogenital opening
- h. Urinary bladder
- i. Urethra

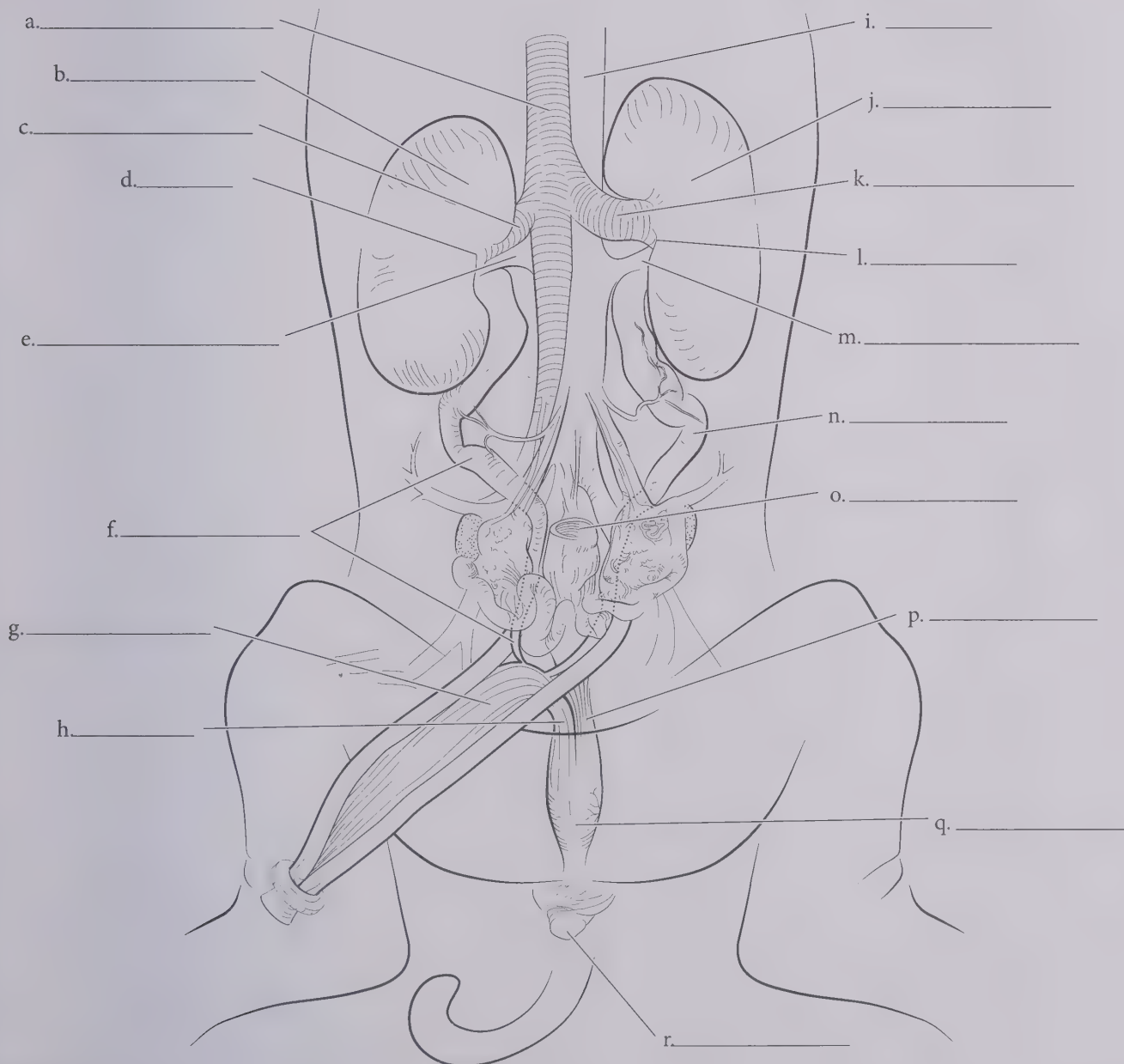
- j. Penis
- k. Aorta
- l. Left kidney
- m. Left renal vein
- n. Hilus

- o. Left renal artery
- p. Left ureter
- q. Colon (cut)

UROGENITAL SYSTEM, FEMALE

There is no difference between males and females in the function or location of the kidneys, ureters, and bladder. However, in the female, the urethra empties into the **urogenital sinus** which then passes wastes to the outside through the **urogenital orifice** located in the urogenital papilla. The **vagina** extends from the **uterus** openings and also enters the urogenital sinus.

Use the same colors for the female urinary organs as you used for the male, but use a different color for those organs that are part of the female reproductive system.



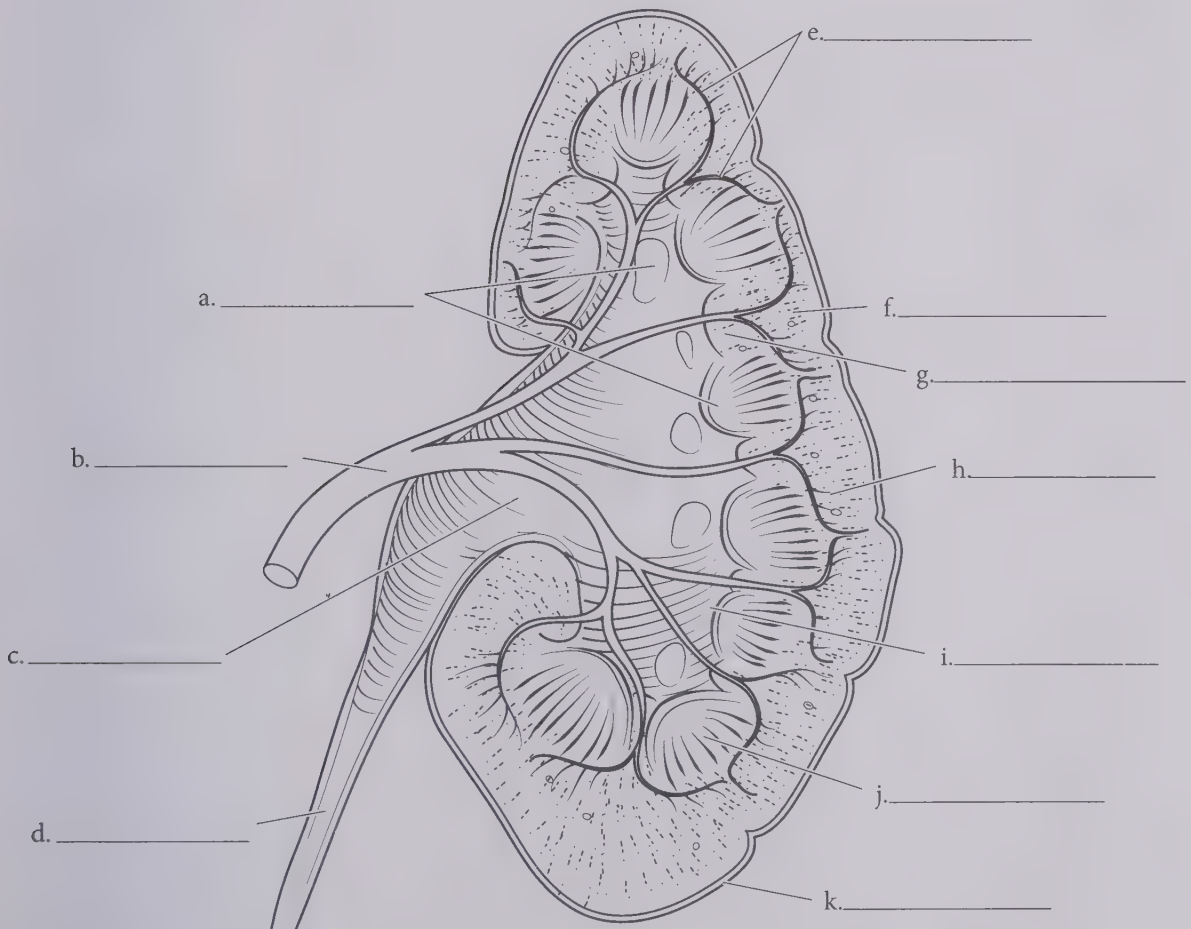
Answer Key:			
a. Caudal vena cava	e. Right renal artery	j. Left kidney	o. Colon (cut)
b. Right kidney	f. Right ureter	k. Left renal vein	p. Vagina
c. Right renal vein	g. Urinary bladder	l. Hilus	q. Urogenital sinus
d. Hilum	h. Urethra	m. Left renal artery	r. Urogenital papilla
	i. Aorta	n. Left ureter	

KIDNEY

The kidneys function in filtering the blood to remove excess water, remove nitrogenous wastes in the form of urea, adjust blood pH by selectively removing hydrogen ions, and maintain blood electrolyte levels by adjusting sodium or chloride ion levels. The urine produced by the kidneys travels through the ureter to the urinary bladder until it is voided to the environment through the urethra. Looking at the interior of the kidney shows that it has several regions; under the protective capsule is the **cortex**; deep to the cortex is the **medulla** which is arranged into **renal pyramids**; and the urine that is formed drains from the

medulla into a collecting region known as the **calyx**. From there, urine passes through the ureter to be stored in the bladder. Blood enters the kidney through the renal artery which divides into several smaller **interlobular arteries** that turn perpendicularly to form the **arcuate** vessels that pass at the interface between the cortex and medulla. From here, blood wastes are filtered out in the **nephrons** which are the functional units of the kidney's ability to produce urine.

Use different colors to designate the cortex, medulla, and calyx regions.



Answer Key:

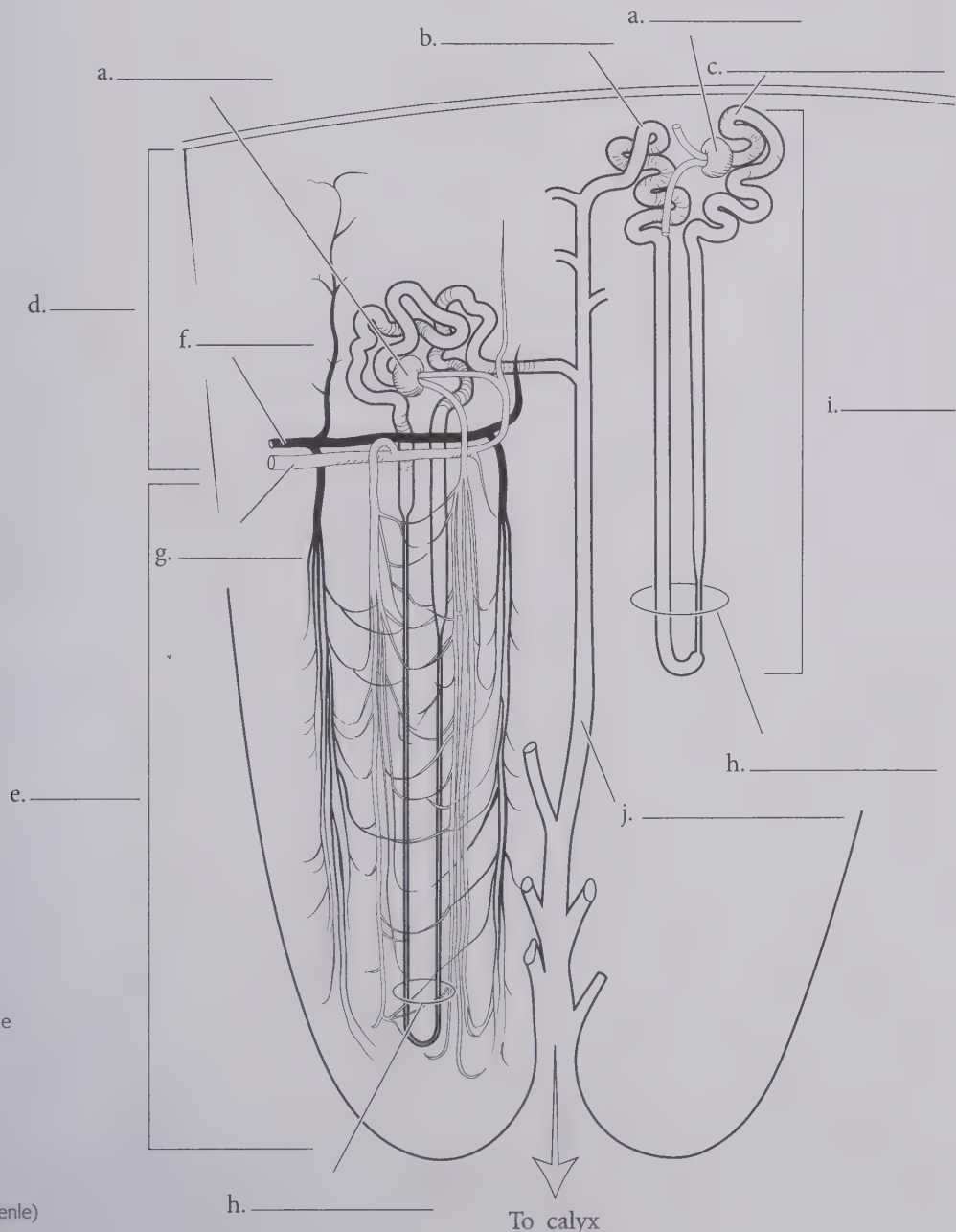
- | | |
|--------------------|----------------------------|
| a. Renal papillae | f. Renal cortex |
| b. Renal artery | g. Renal column |
| c. Renal pelvis | h. Interlobular vessel |
| d. Ureter | i. Renal calyx |
| e. Arcuate vessels | j. Renal pyramid (medulla) |
| | k. Fibrous capsule |

NEPHRON

Blood wastes are filtered out to form urine in the nephron. The arcuate artery branches so that the blood enters the cortex where the vessel gives rise to a small spherical mass of capillaries, called the **glomerulus**. Liquid leaves the blood through the porous walls of the capillaries and enters the **proximal convoluted tubule**, passes into the **Loop of Henle** (located deeper, in the medulla) and back to the **distal convoluted tubule** located in the cortex. The glomerular filtrate contains many molecules in addition to the wastes that will eventually be eliminated in the urine. Passage through the nephron involves selective reabsorption of water throughout, absorption of valuable nutrients in the proximal tubule, and, when necessary, absorption of sodium or hydrogen ions in

the Loop of Henle. These molecules are reabsorbed into the many capillaries that adjoin the tubule. In the distal convoluted tubule, additional waste materials or drugs may be selectively secreted from the adjacent capillaries into the urine. Urine formed in multiple nephrons then passes into a collecting duct which carries the urine through the medulla, into the calyx, and eventually to the ureter.

Name each part of the nephron as you color it, and describe the functions occurring there. Use the colors you used previously to designate the parts of the nephron found in the cortex or medulla.



Answer Key:

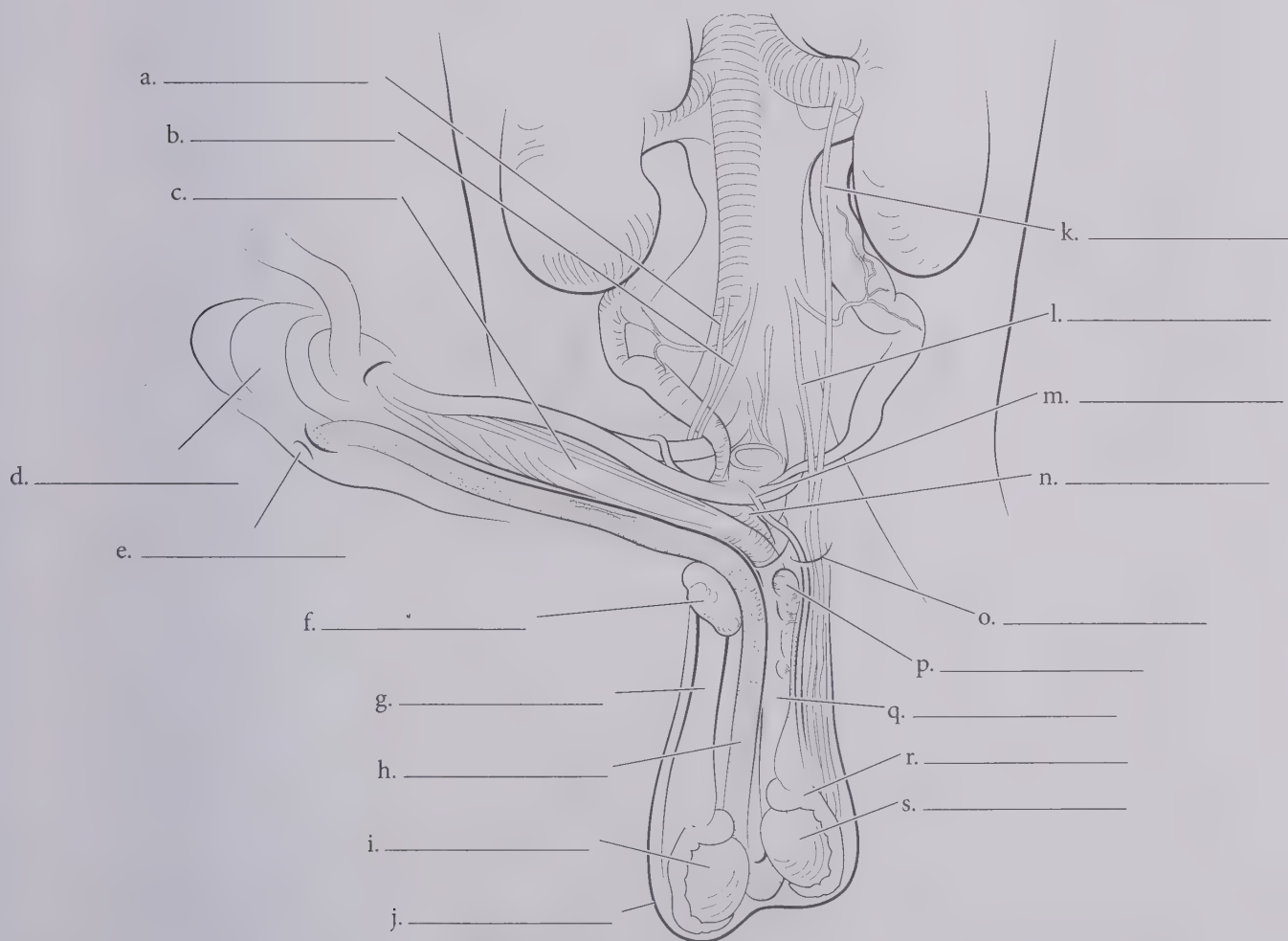
- a. Glomerulus
- b. Distal convoluted tubule
- c. Proximal convoluted tubule
- d. Cortex
- e. Medulla
- f. Arcuate vein
- g. Arcuate artery
- h. Nephron loop (Loop of Henle)
- i. Nephron
- j. Collecting duct

REPRODUCTIVE SYSTEM—MALE

The male **testes** develop dorsal to the coelomic cavity, near the kidneys, but migrate during development to lie in an external pouch, the **scrotum**, ventral to the anus, where the temperature is several degrees cooler than the animal's internal body temperature. In the early fetus, the testes have not yet descended, but in the larger fetal pigs usually studied, they have already migrated to the scrotum. The **testicular artery** and **vein** along with nerves pass into the scrotum through an opening in the body wall called the **inguinal canal**. After the animal reaches sexual maturity, sperm is formed in the testes and passes through or is stored in the **epididymis** which extends alongside the testes and continues into the **ductus deferens**. The ductus deferens from each testis then passes through the inguinal canal and enters the urethra prior to the point where it enters the penis.

In the pig, the penis is very long and lies in a sheath embedded in the ventral body wall, surrounded by erectile tissue. A retractor muscle pulls the penis back into its sheath after an erection. Accessory glands that are also found in the male reproductive tract include the **prostate**, **seminal vesicles**, and **bulbourethral glands**, all of which secrete part of the seminal fluid which carries and nourishes the sperm.

Begin by coloring the urinary system structures as you did before. Name and color the structures in the reproductive system beginning with the testes and continuing in the order in which the sperm pass through the structures. This sequence will help you in remembering the names and functions.



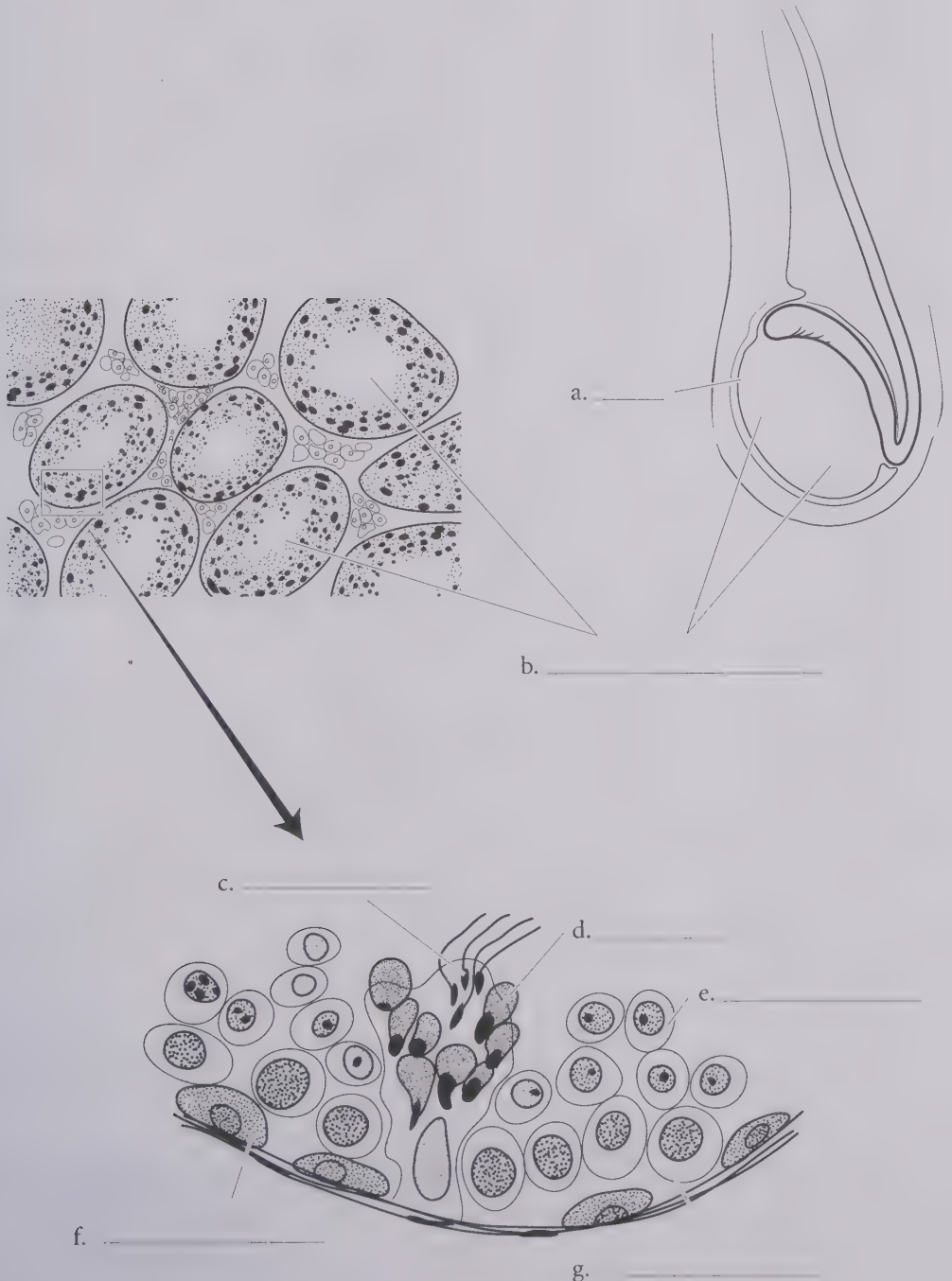
Answer Key:

- | | | |
|----------------------------|-----------------------------------|------------------------|
| a. Right testicular vein | h. Penis | o. Inguinal canal |
| b. Right testicular artery | i. Right testis | p. Bulbourethral gland |
| c. Urinary bladder | j. Scrotum | q. Urethra |
| d. Umbilical cord | k. Left testicular vein | r. Epididymis |
| e. Urogenital opening | l. Left testicular artery | s. Left testis |
| f. Preputial gland | m. Ductus deferens (Vas deferens) | |
| g. Spermatid cord | n. Seminal vesicle | |

MALE HISTOLOGY

Within the testis, sperm are produced in the seminiferous tubules through a series of steps called spermatogenesis. Around the periphery of the tubules are found the **spermatogonia**. After the pig reaches sexual maturity, hormones trigger the division of these cells so that each can produce two daughter cells—one remains at the periphery as a spermatogonium while the other moves toward the lumen of the tubule and differentiates into the **primary spermatocyte**. This cell undergoes meiosis—a particular form of cell division that only occurs in the process leading to formation of gametes. The primary spermatocyte is diploid, i.e., it possesses two copies of each chromosome. During

meiosis, the cell will duplicate its chromosomes and then divide twice—resulting in cells that only contain one copy of each chromosome (haploid). Cells which are in the middle of meiosis (have divided the first time) are called **secondary spermatocytes**, while the final product of meiosis is called a **spermatid**. Each primary spermatocyte gives rise to two secondary spermatocytes and four spermatids. Spermatids then undergo further differentiation called spermiogenesis to produce mature, flagellated **spermatozoa**. Since each step takes them closer to the lumen of the tubule, the spermatozoa are able to migrate out of the testes to the epididymis.



Answer Key:

- a. Testis
- b. Seminiferous tubules
- c. Spermatozoa
- d. Spermatids
- e. Secondary spermatocytes
- f. Spermatogonia
- g. Primary spermatocytes

REPRODUCTIVE SYSTEM—FEMALE

The female reproductive tract includes two **ovaries** which produce eggs that pass through the **fallopian tubes** to the uterus. The fetal ovaries are small, oval organs lying near the dorsal wall of the abdomen, caudal to the kidneys. The mesosalpinx is part of the broad ligament of the uterus which encloses the fallopian tube. In the pig, there is a small **uterine body** with long, convoluted **uterine horns** which are the site of embryo implantation after the eggs are fertilized. In contrast, the human female has no uterine horns but a large uterine body where implantation occurs. The uterus of the pig leads into the vagina which unites with the urethra to form a **urogenital canal** leading to the body surface. In the human, the vagina and urethra open independently on the surface.

Begin by coloring the urinary system structures as you did before. Name and color the structures of the reproductive system beginning with the ovary and continuing in the order in which the egg or developing offspring pass through the structures. This sequence will help you in remembering both the names and functions of each.



Answer Key:

- a. Right ovarian vein
- b. Right ovarian artery
- c. Mesosalpinx

- d. Right ovary
- e. Right horn of uterus
- f. Left ovarian vein
- g. Left ovarian artery

- h. Left ovary
- i. Left horn of uterus
- j. Uterus
- k. Vagina

- l. Urogenital sinus
- m. Urogenital papilla

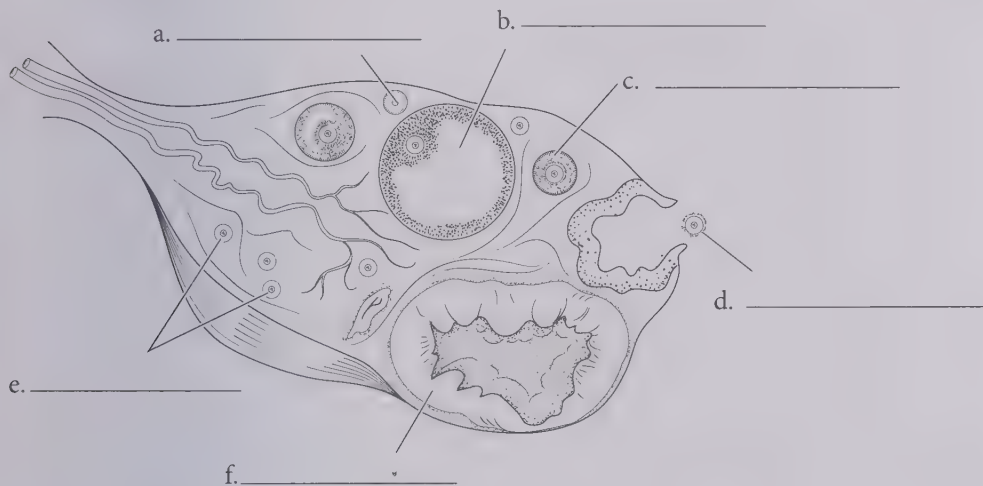
FEMALE HISTOLOGY

Most of the ovary is composed of a cortex containing eggs surrounded by follicular cells, each in various stages of maturation. The periphery of the cortex has several layers of primordial follicles, each with a large primary oocyte surrounded by a layer of granulosa cells. At birth, the primordial follicles contain all the oocytes that the pig will have in its lifetime; no additional follicles develop after birth. Upon stimulation by follicle stimulating hormone (FSH), certain follicles enlarge and move further into the cortex to become primary follicles. The primary oocyte enlarges as food accumulates; granulosa cells multiply and form several layers; surrounding connective tissue forms a follicle covering called the theca; the follicles secrete estrogen to signal the uterus to build up its endometrium to include a functional layer that contains glands and blood vessels, in preparation for implantation of an embryo. As development continues in the ovary to produce the secondary follicle, the oocyte moves to the edge of the follicle, and a fluid-filled space develops in the middle. Although only one follicle normally matures during each cycle in humans, many follicles mature in each ovarian cycle in pigs and other animals that give birth to offspring in litters.

A few hours before ovulation, the primary oocyte in the follicle begins to undergo meiosis—the type of cell division that leads to the production

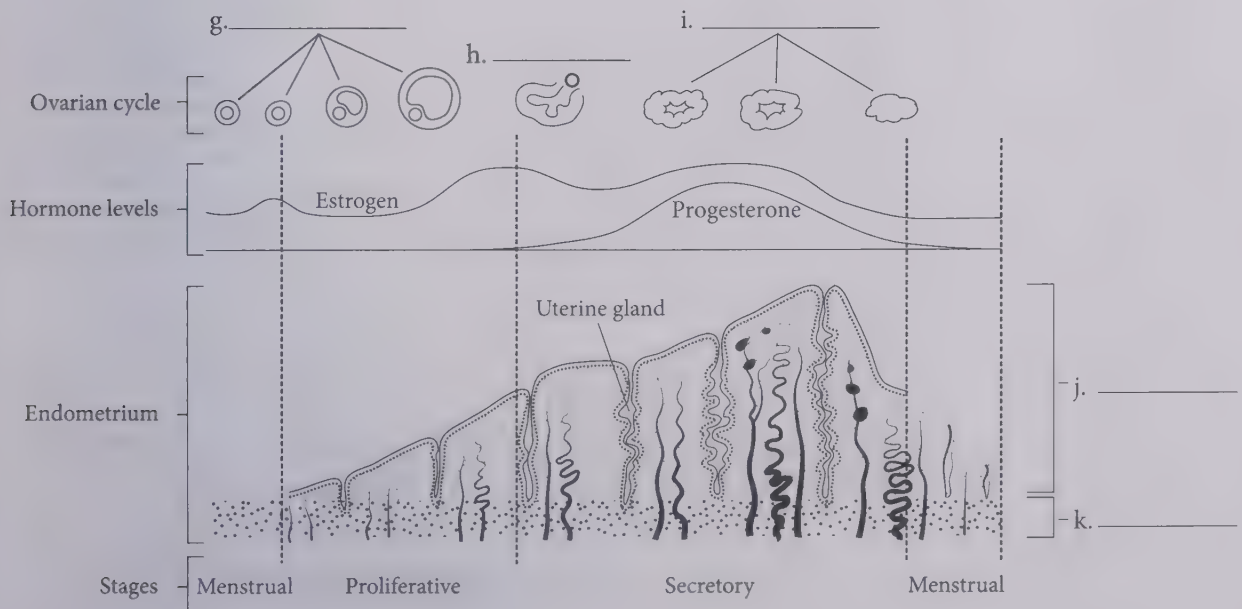
of gametes. The oocyte duplicates its chromosomes and divides once to form a single secondary oocyte, plus a cell known as a polar body that contains half the chromosomes but little cytoplasm and none of the stored food. The second meiotic division that will produce the final haploid gamete from the secondary oocyte is not completed until the cell has been penetrated by the head of a spermatozoan. Mature follicles containing the secondary oocyte then accumulate enough liquid that they rupture at the surface of the ovary, releasing the egg into the coelom, where it enters the uterus through the fallopian tubes. The ruptured follicle (now called the corpus luteum) enlarges and continues to secrete hormones—particularly progesterone which maintains the endometrial lining to prepare for embryo implantation.

The lower figure shows how follicular and hormonal changes influence uterine wall preparation for embryo implantation in humans. In pigs, estrogen is secreted from maturing follicles, inducing estrus just before the eggs are released. Following ovulation, the corpora lutea produce progesterone to prepare the uterus as in humans. When pregnancy does not occur, the estrus cycle in pigs lasts approximately 21 days.



Answer Key:

- a. Primary oocyte
- b. Secondary follicle
- c. Primary follicle
- d. Secondary oocyte
- e. Primordial follicles
- f. Corpus luteum
- g. Preovulatory phase
- h. Ovulation
- i. Postovulatory phase
- j. Functional layer
- k. Basal layer

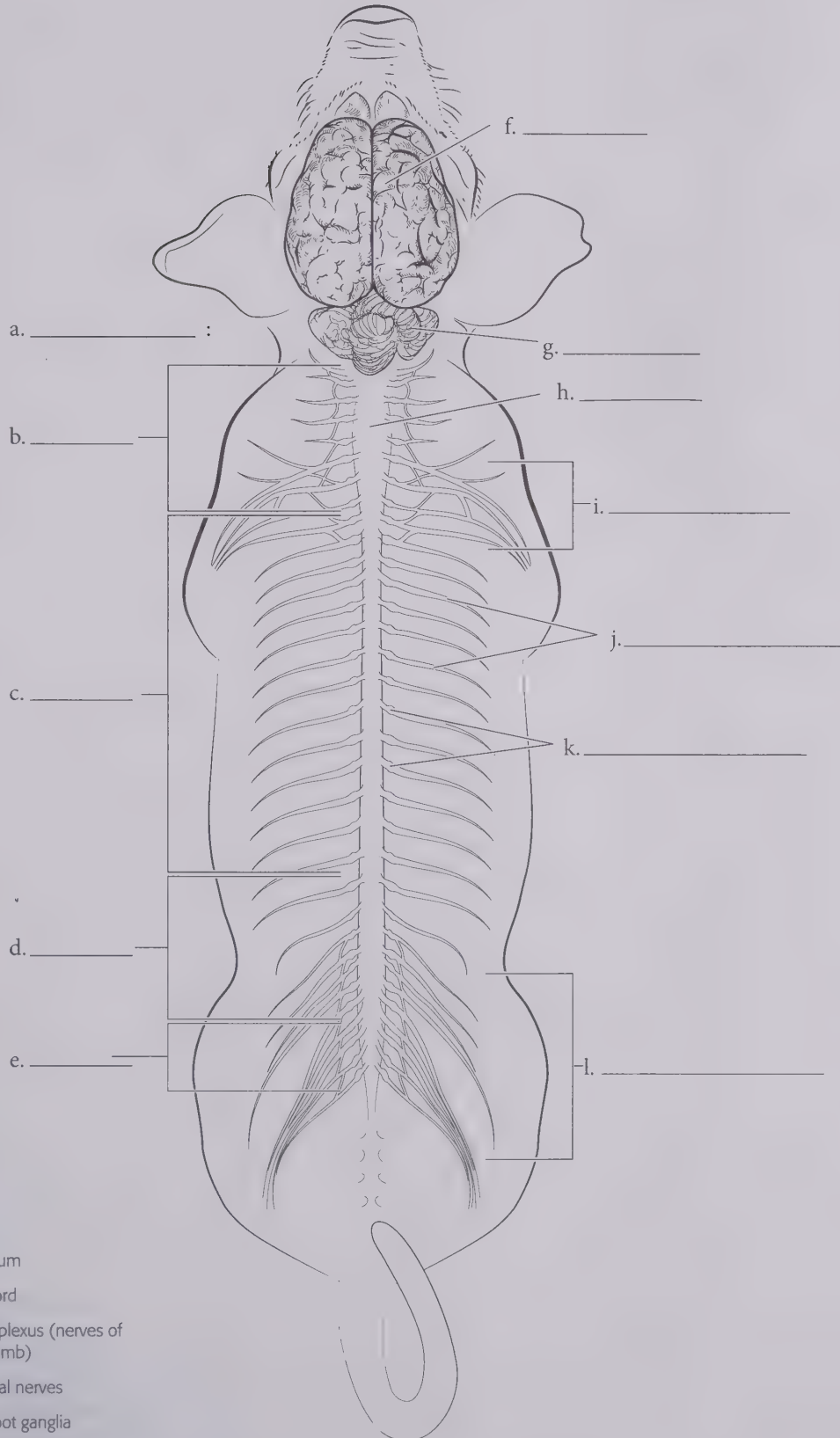


NERVOUS SYSTEM, DORSAL VIEW

The nervous system functions to sense and respond to the external environment, to sense and respond to changes in the internal environment, and to communicate messages between parts of the body. In order to accomplish this, the nervous system includes sense organs (eye, ear), other sensory tissues (taste buds, olfactory tissue, pressure sensors), both sensory and motor neurons to conduct impulses, and the central nervous system.

The central nervous system includes the **brain** and **spinal cord**, which function to integrate and coordinate activities throughout the body. The brain is located inside the cranium and is continuous with the spinal cord stretching along the dorsal midline of the body. **Cranial nerves** from the head region enter the brain directly, while communication with the rest of the body depends upon **spinal nerves** entering the spinal cord. These neurons located outside the central nervous system are called the peripheral nervous system and can be divided into sensory or motor neurons, depending upon whether they convey information toward or away from the central nervous system. Many nerves are mixed in nature—including both sensory and motor nerve fibers.

Motor neurons of the peripheral nervous system may be divided into somatic motor neurons controlling voluntary muscles and autonomic motor neurons which regulate smooth muscle, cardiac muscle, and glands. The autonomic neurons may be further divided into the sympathetic and parasympathetic systems, which often provide organs with compensatory signals. For example, sympathetic stimulation is responsible for dilating the pupil of the eye in low light, while parasympathetic stimulation will constrict the pupil when light levels are higher.

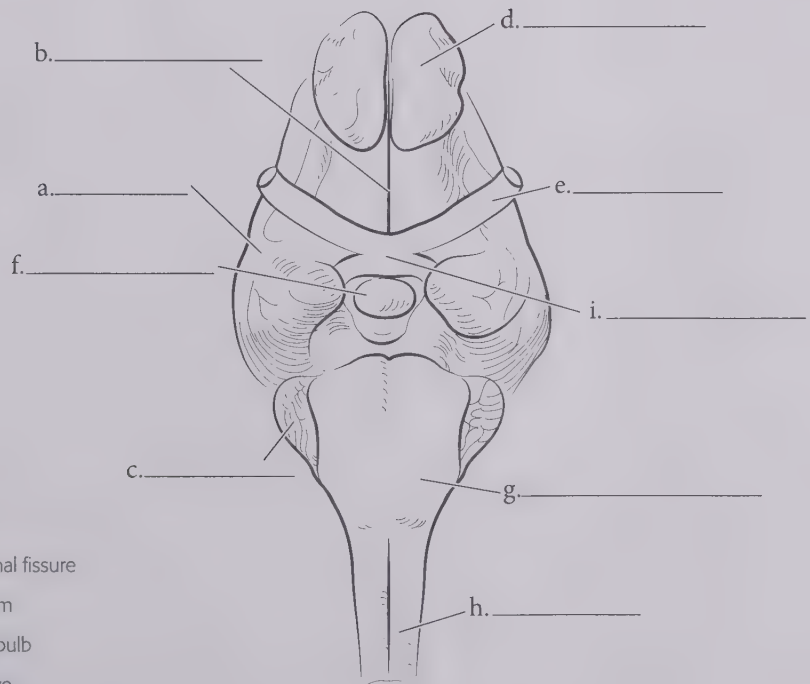
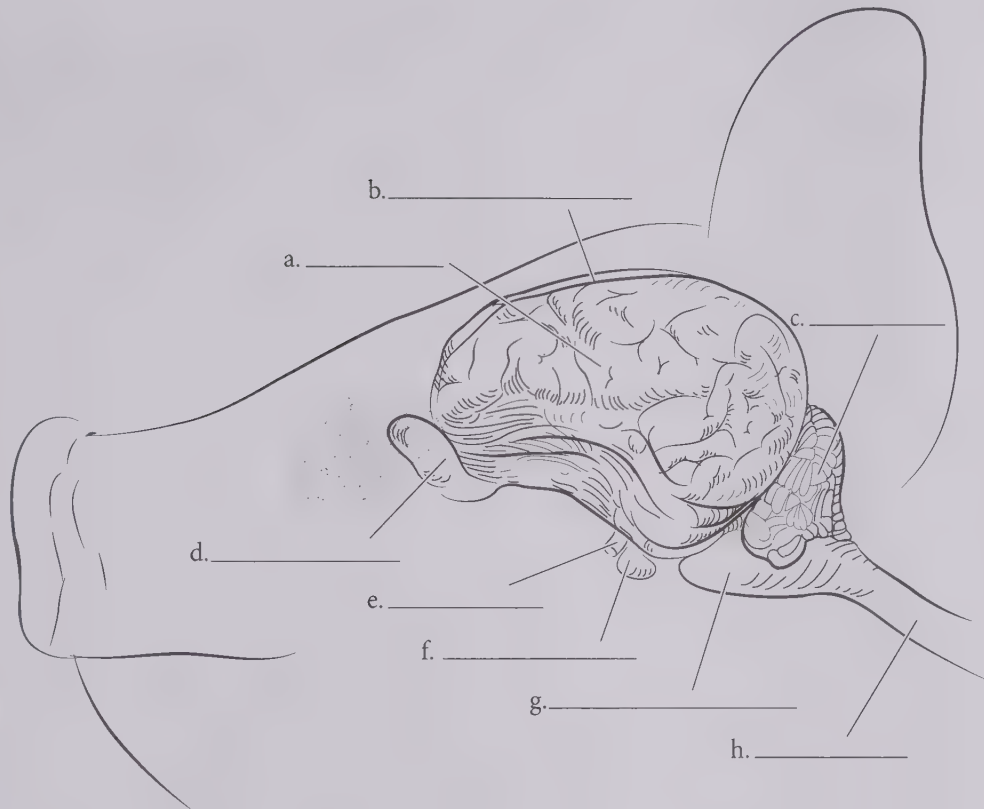


Answer Key:

- | | |
|--------------------|--|
| a. Spinal nerves | g. Cerebellum |
| b. Cervical nerves | h. Spinal cord |
| c. Thoracic nerves | i. Brachial plexus (nerves of the forelimb) |
| d. Lumbar nerves | j. Intercostal nerves |
| e. Sacral nerves | k. Dorsal root ganglia |
| f. Cerebrum | l. Lumbar and sacral plexuses (nerves of the hindlimb) |

LATERAL BRAIN, VENTRAL BRAIN

The brain is located inside the cranium, and derives from the enlarged anterior portion of the dorsal hollow nerve cord as in all vertebrates. Similar to other mammals, the **cerebrum** is the largest section (although not as large as in humans). Cranial nerves from the head region enter the brain directly, including the **optic nerve** shown entering the ventral side of the brain. Anteriorly, the olfactory bulb is close to its source of stimulation—the nasal conchae containing smell receptors. The **pituitary gland** on the ventral aspect of the brain secretes hormones which control the other endocrine glands and influence growth, metabolism, and maturation. Posterior to the cerebrum is the **cerebellum**, which functions largely in muscular coordination, and the **medulla oblongata**, which controls many involuntary activities such as heart beat, blood pressure, salivation, swallowing, and breathing.

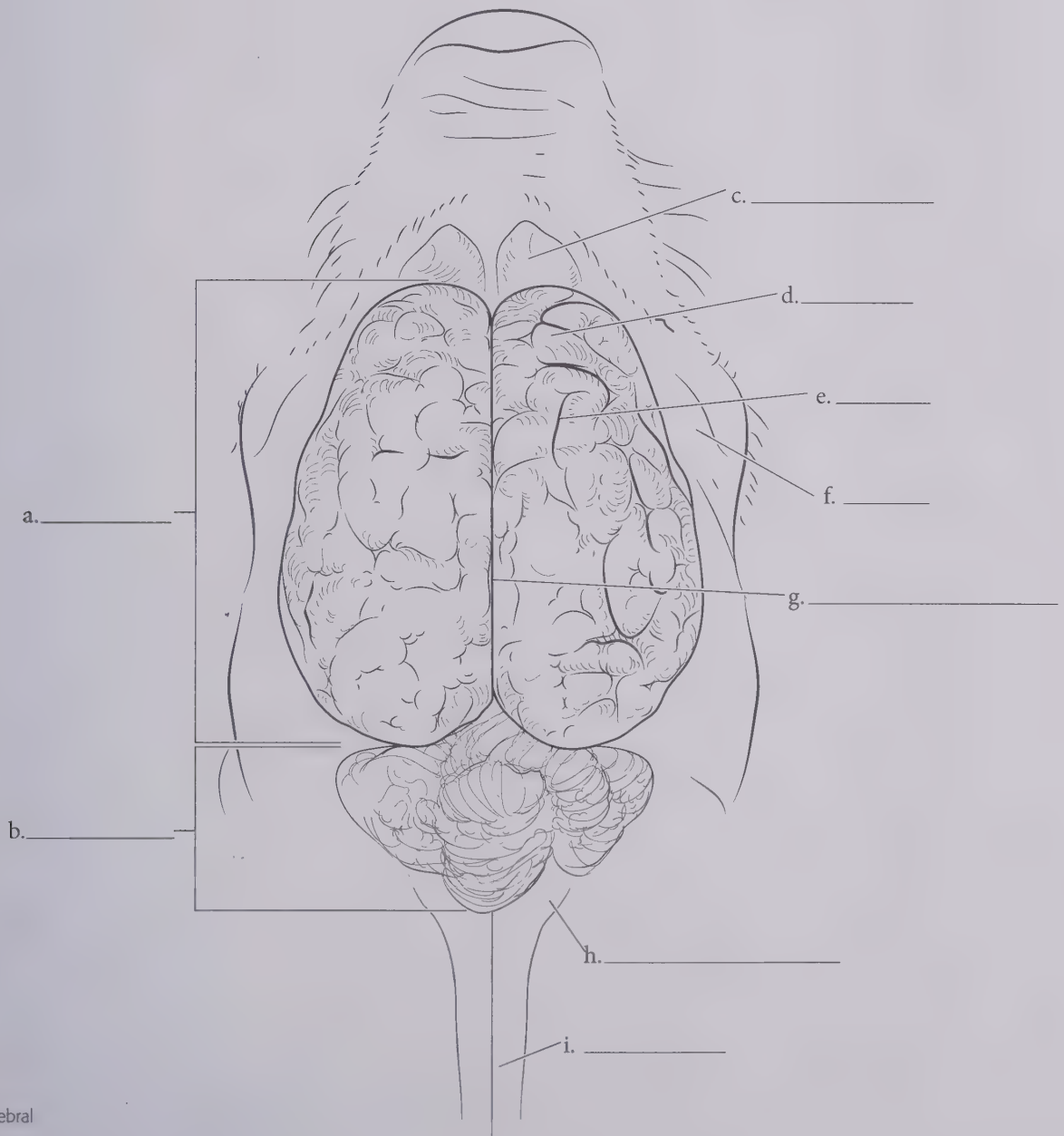


Answer Key:

- a. Cerebrum
- b. Longitudinal fissure
- c. Cerebellum
- d. Olfactory bulb
- e. Optic nerve
- f. Pituitary gland
- g. Medulla oblongata
- h. Spinal cord
- i. Optic chiasm

DORSAL BRAIN

The surface of the cerebral cortex is highly convoluted and densely packed with nerve cells; its area is increased by having a series of ridges called **gyri** and creases called **sulci**. The cerebrum is divided into left and right halves by the **longitudinal cerebral fissure**. Each region of the cerebral cortex has specific functions that may be sensory, motor, or associative in nature. Within these regions, each point may control or receive input from a specific part of the body.



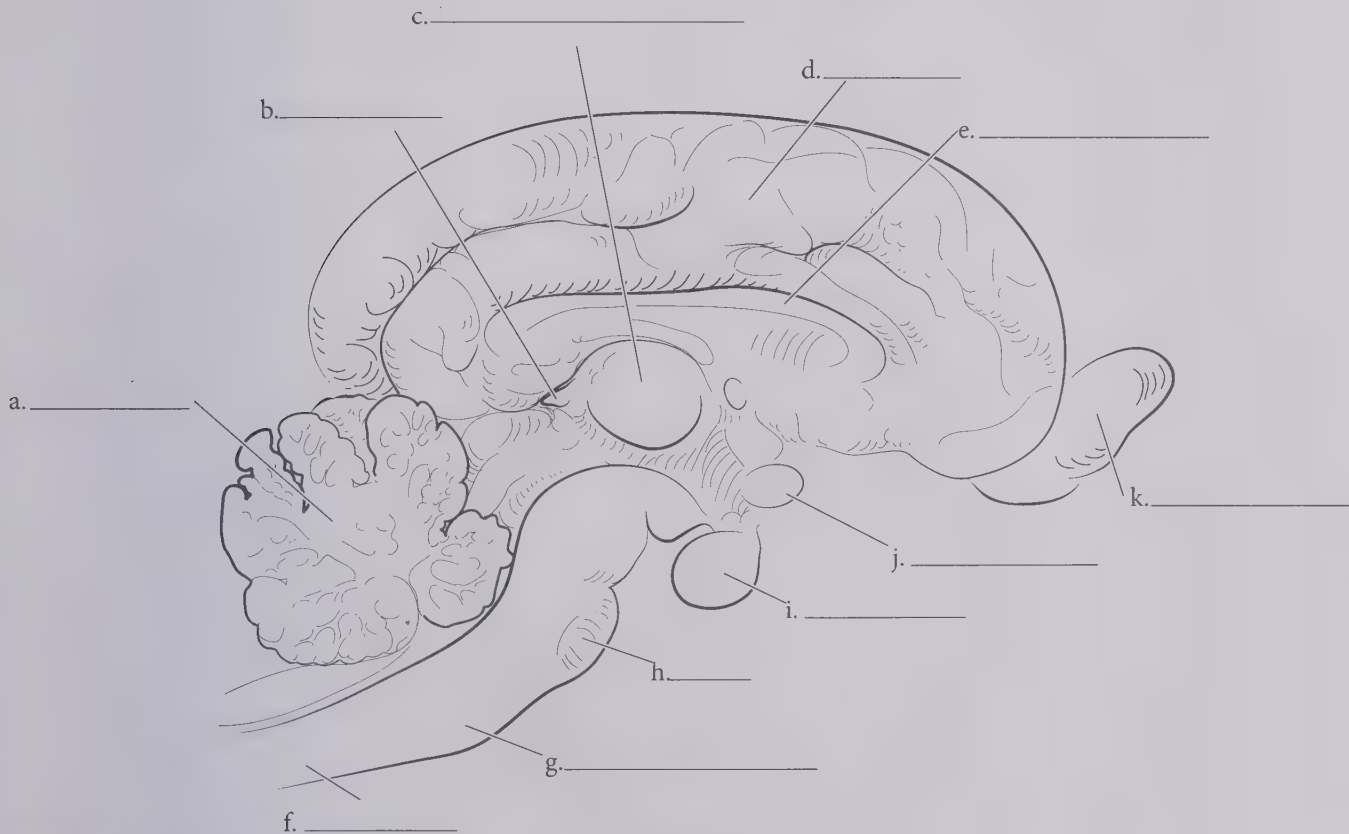
Answer Key:

- a. Cerebrum
- b. Cerebellum
- c. Olfactory bulb
- d. Gyrus
- e. Sulcus
- f. Eye
- g. Longitudinal cerebral fissure
- h. Medulla oblongata
- i. Spinal cord

SAGITTAL BRAIN

A midsagittal view of the brain shows structures deep within the brain that are not obvious from the surface. The **corpus callosum** is a region with bundles of nerve fibers on the base of the longitudinal fissure that function in connecting the two hemispheres of the cerebrum. The **pineal body** is a stalked gland that releases the hormone melatonin during darkness; this is thought to influence rhythms of activity. The **interthalamic adhesion** consists of tissue that contacts the medial surfaces of the thalamus regions on both sides of the brain. The **optic chiasma** is the point where the two optic nerves cross before entering the brain—visual information from the right eye enters the left side of the brain and vice versa.

In the region of the brain just anterior to the spinal cord and medulla oblongata lies the pons, which contains fibers that connect the two hemispheres of the cerebellum. Loosely attached at the base of the brain is the pituitary gland; the posterior pituitary secretes hormones made in the hypothalamus (oxytocin and antidiuretic hormone) while the anterior pituitary makes and secretes a number of hormones, including growth hormone, thyroid-stimulating hormone, and follicle-stimulating hormone.



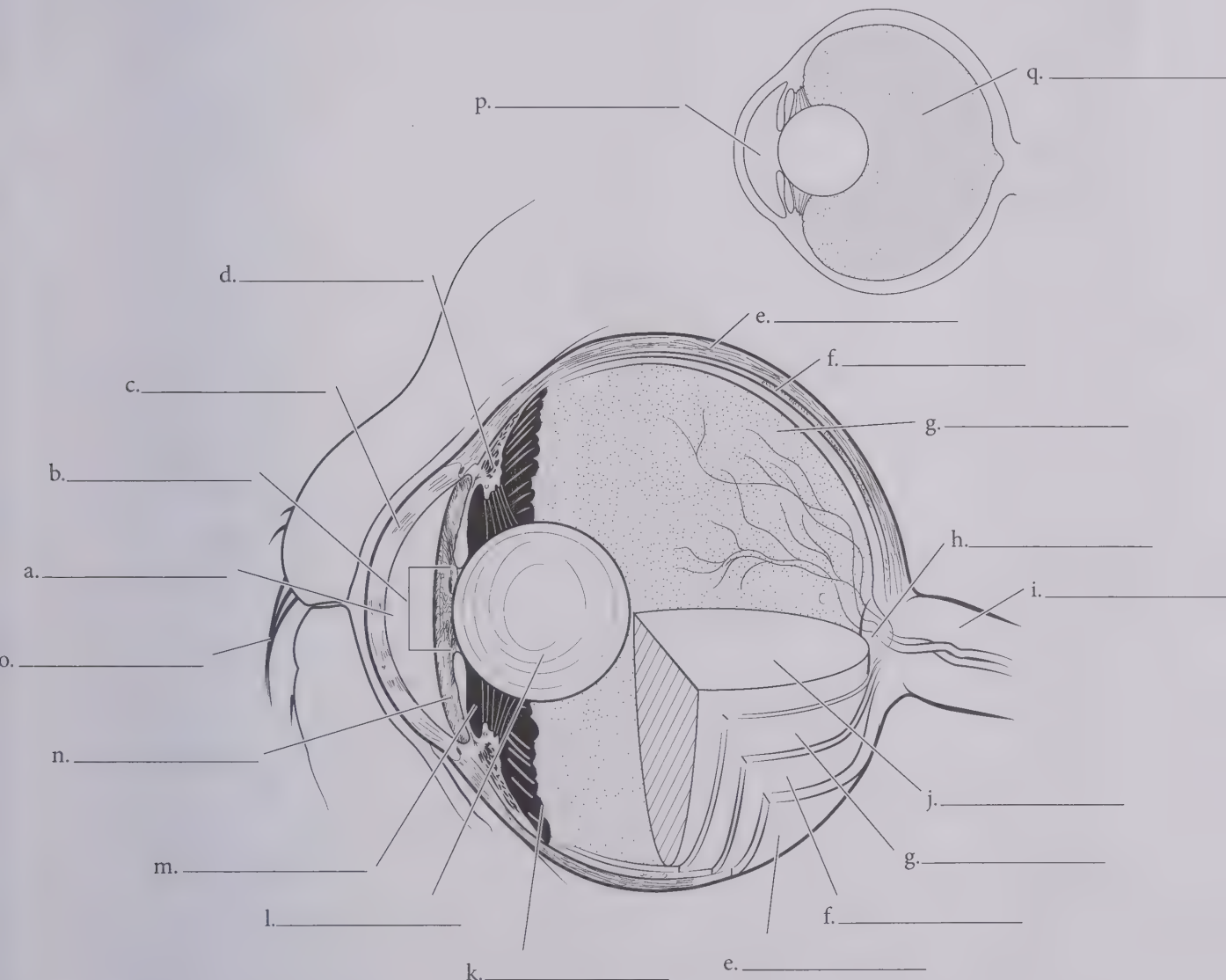
Answer Key:

- a. Cerebellum
- b. Pineal body
- c. Interthalamic adhesion
- d. Cerebrum
- e. Corpus callosum
- f. Spinal cord
- g. Medulla oblongata
- h. Pons
- i. Pituitary gland
- j. Optic chiasma
- k. Olfactory bulb

EYE

The path of light entering the mammalian eye begins with passage through the clear **cornea** and enters the posterior chamber through a hole in the **iris** called the **pupil**. Light then passes through the **lens** which inverts and focuses the image on the sensory cells of the **retina**, which is complex and multilayered. When a photon activates a retinal cell, an impulse is generated and sent to the brain through the optic nerve. At the opening to the optic nerve, called the optic disc, there are no light receptors.

The lens is held in place, and its shape changed to focus the image, by a muscular **ciliary body** located just behind the iris. The irregular junction of the ciliary body with the complex layers of the retina is a zone called the **ora serrata**. The eyeball wall consists of the outer tough, white **sclera** (which is clear in front to form the cornea), the black **choroid**, and the internal, complex, sensory retina. The cavity posterior to the lens is filled with **vitreous humor**, a clear, gelatinous material that fills the eyeball to maintain its shape while allowing light to pass.

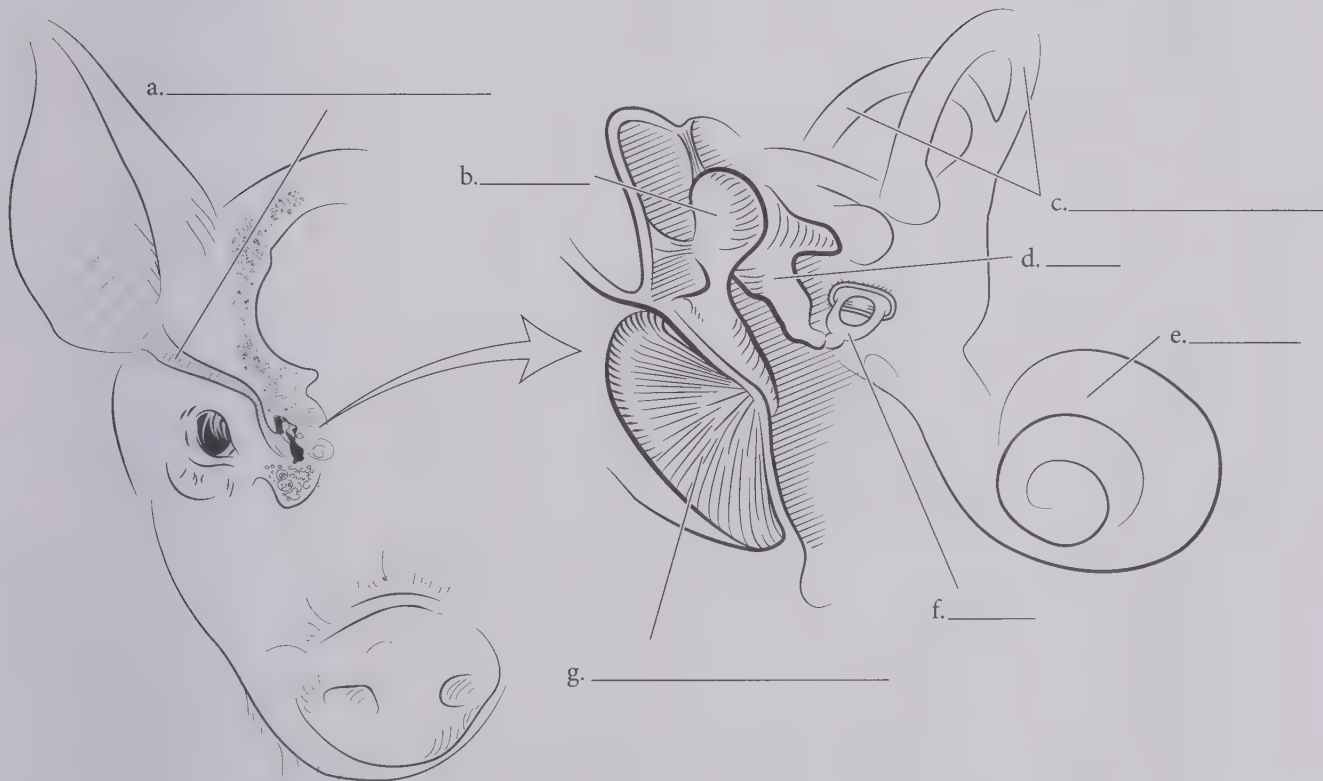


Answer Key:

- | | | |
|---------------------|-------------------|---------------------------------------|
| a. Anterior chamber | g. Retina | m. Posterior chamber
(behind iris) |
| b. Pupil | h. Optic disk | n. Iris |
| c. Cornea | i. Optic nerve | o. Eyelash |
| d. Ciliary body | j. Vitreous humor | p. Anterior cavity |
| e. Sclera | k. Ora serrata | q. Posterior cavity |
| f. Choroid | l. Lens | |

EAR

The **external auditory** canal leads from the external ear, or pinna, into the inner ear. At the end of the auditory canal is the **tympanic membrane**, which vibrates when sound waves impact it. The vibration of the tympanic membrane is transmitted sequentially through a series of three small bones: the **malleus**, **incus**, and **stapes**. Vibration of the stapes, in turn, vibrates the oval window of the **cochlea**; fluid in the cochlea then vibrates certain sensory cells in the organ of Corti to send auditory sensory messages to the brain via the auditory nerve. Another part of the inner ear consists of the semicircular ducts, a set of three fluid-filled canals set approximately perpendicular to each other in three separate planes; movement of the fluid in these ducts provides information crucial to balance.

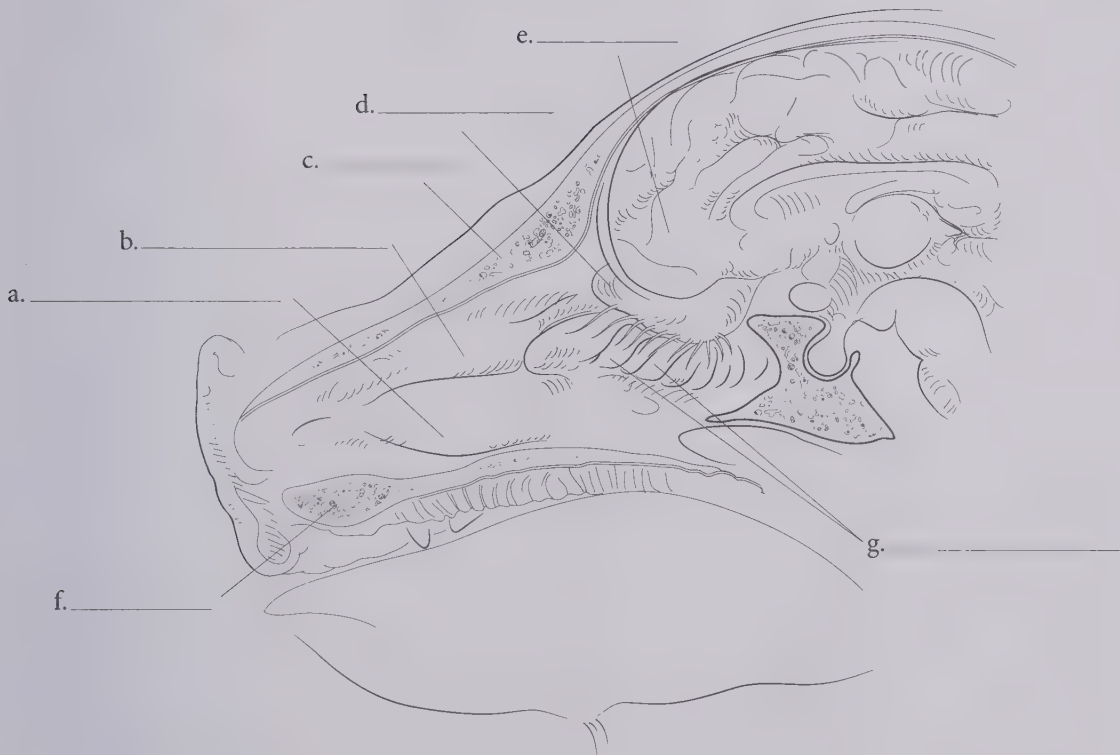


Answer Key:

- a. External auditory canal
- b. Malleus
- c. Semicircular ducts
- d. Incus
- e. Cochlea
- f. Stapes
- g. Tympanic membrane

NOSE

The passage of air entering the nasal cavity flows between folds of tissue called the ventral and dorsal nasal conchae that increase the surface area largely for adapting the temperature and humidity of the air entering the respiratory system. The ethmoid conchae lie high in the caudal end of the nasal cavity, and they are the primary location for olfactory receptors, which are located on the cilia of specialized sensory neurons; activated neurons send the signal through the olfactory nerve to the olfactory lobe of the cerebrum. Note how close the olfactory lobe is to the ethmoid conchae.

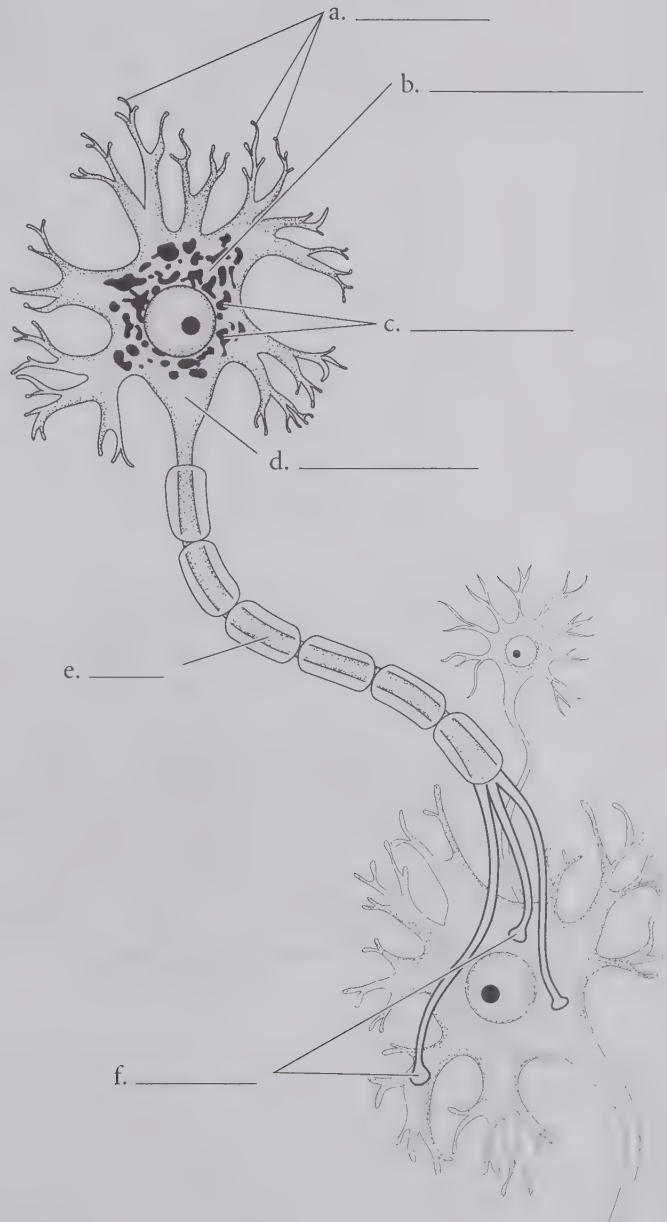


Answer Key:

- a. Ventral nasal concha
- b. Dorsal nasal concha
- c. Nasal bone
- d. Olfactory bulb
- e. Cerebrum
- f. Hard palate
- g. Ethmoid conchae

NEURON

The **neuron**, or nerve cell, functions to conduct electrical impulses in the nervous system. The central part of a neuron consists of the cell body which contains a nucleus and large amounts of the protein synthesis machinery called rough endoplasmic reticulum. When nerve cells are stained with a basic dye, these regions stain intensely and are called **Nissl bodies**. Each neuron has a branched structure known as **dendrites** that convey electrical impulses toward the cell body, and an **axon** that continues transmission of that impulse away from the cell body. The region where the axon attaches to the cell body is known as the **axon hillock** and is responsible for controlling whether incoming impulses are sufficient to send the impulse out through the axon. The axon ends at a **synapse** where the impulse is transmitted to an adjoining neuron via a chemical neurotransmitter.

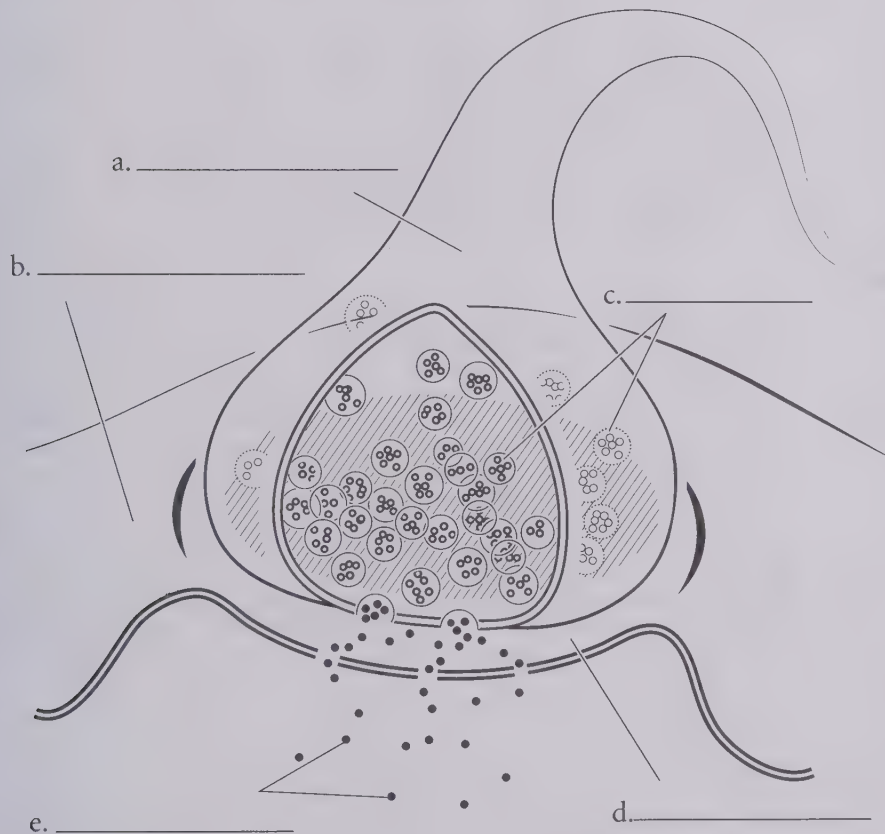


Answer Key:

- a. Dendrites
- b. Nerve cell body
- c. Nissl bodies
- d. Axon hillock
- e. Axon
- f. Synapses

SYNAPSE

Synapses are connections where impulses are transmitted from the axon of one cell—the presynaptic neuron—to a second cell—the postsynaptic neuron. The terminal portion of the presynaptic axon contains small vesicles containing a chemical neurotransmitter. When an electrical impulse travels down the axon and reaches the synapse, these vesicles fuse with the cell membrane, spilling the neurotransmitter contents into the space between the cells, called the **synaptic cleft**. Special receptors in the membrane of the postsynaptic cell detect the presence of neurotransmitter and initiate the electrical impulse again. Thus, neural impulses are electrical as they pass along the length of each neuron, but chemical as they are transmitted from one cell to the next.



Answer Key:

- a. Presynaptic neuron
- b. Postsynaptic neuron
- c. Synaptic vesicles
- d. Synaptic cleft
- e. Neurotransmitter

Many metabolic functions are coordinated throughout the body using blood-borne chemicals on a slower time scale than possible with the electrical impulses of the nervous system. This system, called the endocrine system, relies on sensing the internal environment and subsequent release of chemical messengers called **hormones** into the bloodstream for delivery to target cells at some distance away. Many hormones affect cells throughout the body; others have specific targets in one or more organs.

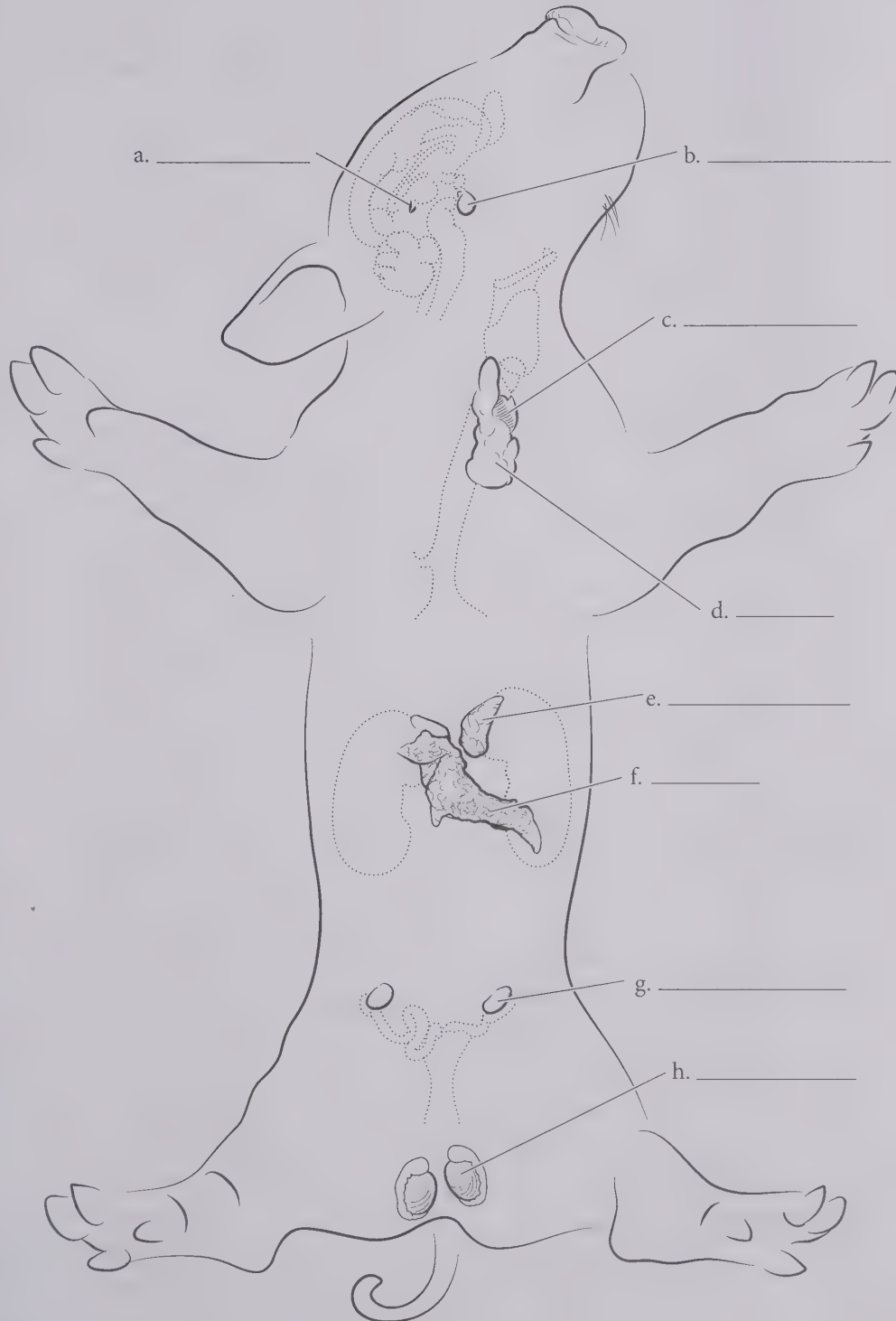
Some hormones are peptides, such as thyroid stimulating hormone (TSH) or adrenocorticotrophic hormone (ACTH). Other hormones are steroid molecules, such as estrogen, testosterone, or cortisol. In order for a hormone to affect a cell or tissue, that cell must express receptors for the hormone. The type of receptor is coordinated both to the type of hormone and to the mechanism by which the hormone functions. Peptide hormones that cannot enter cells unassisted will bind to a cell surface receptor that transmits its message across the cell membrane chemically. Steroid hormones, on the other hand, cross the cell membrane easily and bind to intracellular receptors; the hormone receptor complex typically binds to defined stretches of DNA to control transcription of certain genes. Other hormones exhibit other mechanisms of action. In addition to their direct effects on target organs, many hormones provide feedback to the organs that produce them, reducing the hormone production when the effect has been adequate.

Although the brain's control mechanisms are primarily electrical, three regions are also important in chemical control through the endocrine system. The pineal gland secretes melatonin, important in the pig and other mammals (not humans) in controlling the time of year when estrus cycles occur. The pituitary gland affects many organs throughout the body and has two regions. The posterior pituitary releases two hormones produced by the hypothalamus – antidiuretic hormone which controls water retention by the kidney, and oxytocin which stimulates milk release during suckling among other effects. The anterior pituitary is an epithelial-derived gland that produces and releases at least seven hormones. Growth hormone stimulates growth of many tissues throughout the body. TSH causes the thyroid gland to secrete thyroxine which stimulates metabolism in all tissues. ACTH induces the adrenal cortex to produce steroid hormones that regulate glucose metabolism, among other things. Luteinizing hormone and follicle-stimulating hormone are involved in functioning of both ovaries and testes. Prolactin stimulates production of milk in mammals. Melanocyte-stimulating hormone has little known effect in mammals, although it may stimulate the production of melanin pigment. While the pituitary gland secretes these many hormones that control many functions throughout the body, it is also controlled in part by hormones – released from the hypothalamus, another instance of chemical regulation by regions of the brain.

The pancreas is an endocrine organ as well as a digestive organ since it provides both digestive enzymes that are transported directly into the small intestine and the hormones insulin and glucagon that regulate glucose metabolism throughout the body. Insulin is released when glucose levels are high in the blood; it induces all cells to take up and metabolize glucose and makes the liver take up excess glucose to store in the form of glycogen. Glucagon has the opposite effect on the liver, inducing glycogen breakdown and release to increase blood levels of glucose.

Sex organs also release hormones. The testes release testosterone in the male, while the ovary produces estrogens and progestins.

The **thyroid gland** in the neck region secretes an iodine-containing hormone that generally increases metabolic activity in all cells. The nearby **parathyroid gland** secretes hormones that regulate calcium uptake or deposition within the bones. The **adrenal glands** are located at the anterior tip of the kidneys, and they secrete several hormones. The adrenal medulla produces epinephrine and norepinephrine (also called adrenaline and noradrenalin) that prepare the body for emergencies—increasing heart rate, blood pressure, and blood glucose levels while diverting blood flow away from the skin and digestive organs. This is known as the “flight or fight” response. The adrenal cortex produces cortisol, a steroid hormone that controls certain aspects of glucose metabolism that are important during fasting or intense exercise. Cortisol also has an anti-inflammatory influence on the immune system. In addition, the adrenal cortex provides a hormone that influences the kidney to reabsorb more sodium to decrease sodium loss in the urine, as well as low levels of several steroid sex hormones.

**Answer Key:**

- a. Pineal gland
- b. Pituitary gland
- c. Thyroid gland
- d. Thymus
- e. Adrenal gland
- f. Pancreas
- g. Ovary (female)
- h. Testis (male)

A

Abdominal cavity, 43
 Abdominal region, 25
 Abductors, 21
 Accessory lobe, 59, 61, 77
 Accessory organs, 47
 Acromiotrapezius muscle, 29
 Actin filaments, 41
 Adductor, 21, 27, 35
 Adrenal gland, 135
 Adrenaline, 135
 Adrenocorticotrophic hormone (ACTH), 133
 Adult circulation, 71
 Alimentary canal, 47
 Alveolar ducts, 63
 Alveolar sac, 63
 Alveoli, 61, 63
 Ampullae of duodenum, 55
 Angle of mandible, 17
 Ankle, 7
 Anterior, 1
 cavity, 123
 chamber, 123
 superior iliac spine, 35
 Antidiuretic hormone, 133
 Aorta, 67, 69, 71, 73, 77, 85, 87, 89, 99, 101
 Aortic arch, 71, 73, 75, 79, 81, 83
 Aortic, 95
 Aortic semilunar valve, 83
 Appendicular skeleton, 13
 Arcuate artery, 105
 Arcuate vein, 105
 Arcuate vessels, 103
 Arrector pili muscle, 11
 Arteries, 67, 71
 Arteriole, 71, 97
 Artrioventricular valve, 83

Ascending aorta, 67
 Atlas vertebrae, 15
 Atrium, 71, 73, 75, 77, 79, 81, 83
 Auditory canal, 125
 Auricle, 5, 7, 79
 Axial skeleton, 13
 Axillary, 95
 Axis vertebrae, 15
 Axon, 129
 Axon hillock, 129

B

Basal layer, 113
 Basement membrane, 65
 Basophil, 93
 B cells, 93
 Biceps, 31, 33
 Biceps femoris, 25, 29, 35
 Bicuspid valve, 83
 Bile
 canaliculus, 57
 duct, 55, 57
 Bladder, 45
 Blood flow, 69
 Bones, 13, 19
 Brachial plexus, 115
 Brachialis, 27, 31, 33
 Brachiocephalic (Brachiocephalicus), 25, 27, 31
 artery, 79, 81
 trunk, 45
 vein, 75, 77, 95
 Brain, 115
 dorsal, 119
 lateral, 117
 sagittal, 121
 ventral, 117
 Breathing histology, 65

Bronchi, 59, 61, 63
 Bronchioles, 61, 63
 Bronchus, 59, 61, 77
 Buccinator muscle, 49
 Bulbourethral gland, 107

C

C1-7, 15
 Calcaneus, 15, 35, 37
 Calyx, 105
 Canine tooth, 49, 51
 Capillaries, 63, 71
 Cardiac muscle, 41
 Carotid, 67
 Carotid artery, 45, 75, 77, 79, 81
 Carpal bones, 15
 Carpals, 15
 Cartilage, 13, 63
 Caudal, 1, 3
 Caudal lobe, 59, 61
 Caudal mesenteric, 67, 69
 artery, 85, 87
 vein, 87, 91
 Caudal vena cava, 67, 69, 71, 73, 81, 87, 91, 99, 101
 aperture, 83
 Celiac, 67
 Celiac trunk, 85, 87, 97
 Cell, 41
 Central vein, 57
 Cephalic, 69
 Cephalic vein, 75
 Cerebellum, 115, 117, 119, 121
 Cerebrum, 115, 117, 119, 121, 127
 Cervical, 95
 nerves, 115
 region, 15
 Chief cell, 57

Chondrocytes, 19

Chordae tendinae, 83

Choroid, 123

Cilia, 65

Ciliary body, 123

Circular fold, 57

Circulation

- adult, 71
- fetal, 73

Circulatory

- histology, 93
- system, 67

Circumflex iliac, 67, 69

Cochlea, 125

Coelom, 43

Collagenous fibers, 19

Collecting duct, 105

Colon, 47, 99, 101

Constrictors, 21

Cornea, 123

Coronary artery, 79

Corpus

- callosum, 121
- luteum, 113

Cortex, 103, 105

Cortisol, 133, 135

Coxal bone, 15

Cranial, 1, 3, 69

Cranial lobe, 59, 61

Cranial mesenteric, 67, 69

- artery, 85, 87
- vein, 87, 91

Cranial nerves, 115

Cranial vena cava (Superior vena cava), 45, 73, 75, 79, 81, 83

Cranium, 17

Cystic artery, 55

Cystic duct, 55

D

Deep, 1

Deep digital flexor (Flexor digitorum profundus), 33

Deep digital flexor (Flexor digitorum profundus, Tibialis posterior), 35, 37

Deep femoral, 67, 69

Deltoid, 25, 31

Dendrites, 129

Dermis, 11

Descending aorta, 67

Diaphragm, 43, 45, 67, 69, 77, 87

Digestive organs, ventral arteries of, 85

Digestive system, 47

- histology, 57

Dissection incisions, 23

Distal, 1

- convoluted tubule, 105

Dorsal, 1, 3

- deep shoulder muscles, 39
- heart, 81
- muscles, 29
- neck muscles, 39
- root ganglia, 115

Ductus arteriosus, 73, 77, 79, 83

Ductus deferens, 107

Ductus venosus, 73, 87

Ductus venous, 89

Duodenum, 55, 57

E

Ear, 125

- external, 7

Elastic cartilage, 19

Elastic fibers, 19, 67

Elbow, 7

Endocrine system, 133

Endometrium, 113

Eosinophil, 93

Epidermis, 11

Epididymis, 107

Epiglottis, 51, 53, 59, 65

Epinephrine, 135

Erythrocyte, 93

Esophageal notch of liver, 55

Esophagus, 45, 47, 51, 53, 59, 65, 77

Estrogen, 113, 133, 135

Estrus cycles, 133

Ethmoid conchae, 65, 127

Extensor carpi

- brachialis, 25, 27
- radialis/brachialis, 27, 31, 33
- ulnaris, 31

Extensor digitorum, 31, 35

Extensors, 21

External

- auditory canal, 125
- iliac, 67
- oblique, 25, 27

Eye, 7, 119, 123

Eyelash, 123

F

Fallopian tubes, 111

Female, 9

- histology, 113
- reproductive system, 111
- urogenital system, 101

Femoral, 67, 69

Femur, 15

Fetal circulation, 73

Fibrocartilage, 19

Fibrous capsule, 103

Fibula, 15

Fibularis brevis (Peroneus brevis), 35

Fibularis longus (Peroneus longus), 35

Flexor carpi

radialis, 27, 33

ulnaris, 27, 31

Flexors, 21**Follicle, 113**Follicle stimulating hormone (FSH),
113, 133**Follicles, 11**

Foramen ovale, 73, 83

Foramina, 17

Frontal bone, 17

Frontal plane, 3

Frontal plane, heart, 83

Functional layer, 113

G

Gall bladder, 47, 55

Gastric arteries, 85

Gastric pit, 57

Gastrocnemius, 25, 35, 37

Gastro-splenic, 69

Genital, 67, 69

Glomerulus, 105

Glottis, 51, 53

Glucose metabolism, 133

Gluteus medius, 25, 29, 35

Gluteus superficialis (Gluteus maximus),
25, 29

Goblet cells, 65

Gonadal

artery, 87

vein, 87

Gracilis, 27, 37

Great cardiac vein, 79

Greater trochanter of femur, 35

Great vessels, 77

Growth hormone, 133

Gyrus, 119

H

Hair, 11

Hair follicle, 11

Hard palate, 51, 53, 65, 127

Haversian canal, 19

Head, 5, 7

Head of femur, 37

Head and neck, 53

vessels, 75

Heart, 45, 67, 69, 77

dorsal, 81

frontal plane, 83

vental, 79

Hepatic, 69

artery, 55, 85

artery branch, 57

duct, 55

portal vein, 55, 87

veins, 91

Hepatocytes, 57

Hilum, 99, 101

Hilus, 99, 101

Hind limb, 35

Hip bone, 15

Hissl bodies, 129

Hormone levels, 113

Horn of uterus, 111

Humerus, 15

Hyaline cartilage, 19

Hyoid bone, 51, 53, 59, 65

Hypothalamus, 133

I

Ileum, 57

Iliac, 67, 69

artery, 87, 89

crest of hip bone, 29

vein, 87

Iliofemoral, 95

Iliopsoas, 35, 37

Iliosacral, 95

Incisive bone, 17

Incisor, 49

Incus, 125

Infraorbital foramen, 17

Infraspinatus, 31, 39

Inguinal, 95

Inguinal canal, 107

Insertion, 21

Integumentary system, 11

Intercalated disc, 41

Intercostal, 67, 69

artery, 77

nerves, 115

vein, 77

Interlobular arteries, 103

Interlobular vessel, 103

Internal iliac, 67, 69

Internal thoracic, 67

Interthalamic adhesion, 121

Interventricular septum, 83

Iris, 123

Ischial, 95

J-K

Jugular, 69

Jugular vein, 75

Kidney, 45, 69, 89, 99, 101, 103

Knee, 7

L

L1-5, 15

Lacrimal bone, 17

Large intestine, 45, 47

Laryngopharynx, 51

Lateral, 1
 forelimb, 31
 heart, 75
 muscles, 25

Latissimus dorsi, 25, 27, 29, 31, 33, 39

Lens, 123

Leukocyte, 93

Lingual vein, 75

Liver, 45, 47, 55, 57, 69, 73, 85, 89, 91

Lobules, 57

Long head, 33

Longitudinal cerebral fissure, 119

Longitudinal fissure, 117

Loop of Henle, 105

Lumbar, 95
 nerves, 115
 plexus, 115
 region, 15

Lung, 45, 59, 61, 71

Lutenizing hormone, 133

Lymph
 capillaries, 95
 nodes, 95

Lymphatic system, 95

Lymphocyte, 93

M

Male, 9
 histology, 109
 reproductive system, 107
 urogenital system, 99

Malleus, 125

Mammary
 papilla, 7
 papillae, 9
 vein, 75

Mandible, 17, 49

Mandibular, 95

Marginal papillae, 49, 51

Masseter, 25, 49

Matrix, 19

Maxilla, 17

Maxillary vein, 75

Medial, 1
 epicondyle of humerus, 33
 forelimb, 33
 hind limb, 37

Median sacral, 67

Medulla, 103, 105

Medulla oblongata, 117, 119, 121

Meissner corpuscle, 11

Melanin, 133

Melanocyte-stimulating hormone, 133

Melatonin, 133

Menstrual stage, 113

Mental foramina, 17

Mesenteric, 95

Mesosalpinx, 111

Metabolism, 133

Metacarpal bones, 15

Metatarsal bones, 15

Middle lobe, 59, 61

Mitral valve, 83

Monocyte, 93

Motor neurons, 115

Mouth, 47

Mucosa, 57

Mucous sheet, 65

Muscle histology, 41

Muscles, 21

Muscularis, 57

Myosin filaments, 41

N

Nares, 5, 7

Nasal
 bone, 17, 127
 cavity, 53, 59

 conchae, 65, 127

Nasopharynx, 51

Nephron, 103, 105

Nephron loop, 105

Nerve cell body, 129

Nervous system, dorsal view, 115

Neuron, 129, 131

Neurotransmitter, 131

Neutrophil, 93

Noradrenalin, 135

Norepinephrine, 135

Nose, 127

Nuclei, 41, 65

O

Obturator, 35

Occipital bone, 17

Occipital condyle, 17

Olecranon, 15

Olfactory bulb, 117, 119, 121, 127

Oocyte, 113

Optic
 chiasm, 117
 chiasma, 117
 disk, 123
 nerve, 117, 123

Ora serrata, 123

Oral cavity, 51, 53, 59, 65

Organ, 1

Origin, 21

Oropharynx, 51

Os coxae, 15

Osteocyte, 19

Ovarian
 artery, 111
 cycle, 113
 vein, 111

Ovary, 111, 133, 135

Oxytocin, 133

P

Pacinian corpuscle, 11
 Palmaris longus, 27
 Pancreas, 47, 55, 135
 Pancreatic duct, 55
 Papillary muscle, 83
 Parathyroid gland, 135
 Parietal
 bone, 17
 cell, 57
 Parotid, 95
 duct, 49
 gland, 49
 Patella, 15, 35
 Pectineus, 27
 Pectoral girdle, 13
 Pectoralis major (Pectoralis transversus, Pectoralis superficialis), 27, 33
 Pectoralis minor, 33
 pectoralis acendens, 25, 27
 pectoralis profundus), 25, 27, 31
 Pelvic
 girdle, 13
 region, 25, 27
 Pelvis, 37
 Penis, 99, 107
 Peptide hormones, 133
 Phalanges, 15
 Pharynx, 51
 Phrenic nerve, 77
 Pineal
 body, 121
 gland, 133, 135
 Piniformis, 35
 Pinna, 5, 7
 Pituitary gland, 117, 121, 133, 135
 Placenta, 5, 73
 Planes of section, 3
 Platysma, 27

Pons, 121
 Popliteal, 95
 Portal, 69
 system of veins with organs, 91
 triad, 57
 vein, 55, 91, 97
 vein branch, 57
 Posterior, 1
 cavity, 123
 chamber, 123
 Postsynaptic neuron, 131
 Preovulatory phase, 113
 Preputial gland, 107
 Presynaptic neuron, 131
 Primary follicle, 113
 Primary oocyte, 113
 Primary spermatocytes, 109
 Primordial follicles, 113
 Progesterone, 113
 Progestin, 135
 Prolactin, 133
 Proliferative stage, 113
 Prostate, 107
 Protractors, 21
 Proximal, 1
 Proximal convoluted tubule, 105
 Pulmonary, 67
 artery, 63, 67, 71, 77, 79, 81
 circulation, 71
 semilunar valve, 83
 trunk, 67, 69, 73, 77, 83
 vein, 63, 69, 71, 77, 79, 81
 vein apertures, 83
 Pupil, 123

Q-R

Quadrangle lobe of liver, 55
 Quadratus femoris, 35

Radius, 15
 Rectum, 47, 85, 91
 Rectus
 abdominis, 27
 femoris, 27, 35, 37
 Red pulp, 97
 Renal, 67, 69, 95
 artery, 87, 99, 101, 103
 calyx, 103
 column, 103
 cortex, 103
 papillae, 103
 pelvis, 103
 pyramid, 103
 Renal vein, 87, 99, 101
 Reproductive system
 female, 111
 male, 107
 Respiratory system, 59
 Retina, 123
 Retractors, 21
 Retropharyngeal, 95
 Rhomboideus capitis muscle, 39
 Rhomboideus cervicis muscle, 39
 Rhomboideus thoracis muscle, 39
 Ribs, 15
 Rough endoplasmic reticulum, 129

S

Sacral nerves, 115
 Sacral plexus, 115
 Sacrum, 15
 Sagittal plane, 3
 Sagittal section, head and neck, 53
 Salivary glands, 47, 49
 Sartorius, 27
 Scapula, 15
 Sclera, 123

Scrotal sac, 9
 Scrotum, 107
 Sebaceous gland, 11
 Secondary follicle, 113
 Secondary oocyte, 113
 Secondary spermatocytes, 109
 Secretory stage, 113
 Semicircular ducts, 125
 Semimembranosus (Semimembranous), 25, 27, 35, 37
 Seminal vesicles, 107
 Seminal vessel, 107
 Seminiferous tubules, 109
 Semitendinosus (Semitendious), 25, 27, 35, 37
 Serosa, 57
 Serratus anterior (Serratus ventralis), 25, 27
 Serratus ventralis muscle, 39
 Sex differences, 9
 Short head, 33
 Shoulder region, 25
 Sinuses, 97
 Sinusoids, 57
 Skeletal
 histology, 19
 muscle, 41
 Skeleton, lateral, 15
 Skin histology, 11
 Skull, 13, 17
 Small intestine, 45, 47, 85, 91
 Smooth muscle, 41, 67
 Snout, 7
 Soft palate, 51, 53, 65
 Soleus, 35
 Somatic muscles, 21, 23
 Spermatic cord, 107
 Spermatids, 109
 Spermatogonia, 109
 Spermatozoa, 109

Spinal cord, 115, 117, 119, 121
 Spinal nerves, 115
 Spine of scapula, 31, 39
 Spinotrapezius muscle, 29
 Spinous processes of vertebrae, 29
 Spiral colon (Large intestine), 45, 47, 85, 91
 Spleen, 45, 97
 Spleen histology, 97
 Splenic artery, 85, 97
 Splenic vein, 91, 97
 Splenius muscle, 39
 Stapes, 125
 Sternohyoid, 25, 27
 Sternomastoid, 25, 27
 Sternum, 15
 Steroid hormones, 133
 Stomach, 45, 47, 57, 85, 91, 97
 Striations, 41
 Subclavian, 67, 69
 Subclavian artery, 45, 75, 77, 79, 81
 Sublingual duct, 49
 Sublingual gland, 49
 Submandibular duct, 49
 Submandibular gland, 49
 Submucosa, 57
 Subscapularis, 33
 Sulcus, 119
 Superficial, 1
 Superficial digital flexor (Flexor digitorum superficialis), 33, 37
 Superior gemellus, 35
 Supraspinatus, 31, 33, 39
 Swallowing, 53
 Sweat gland, 11
 Sympathetic trunk, 77
 Symphysis pubis, 37
 Synapses, 129, 131
 Synaptic cleft, 131
 Synaptic vesicles, 131

System, 1
 Systemic circulation, 71

T
 T1-15, 15
 Tail, 7, 37
 Tarsal bones, 15
 T cells, 93
 Teeth, 17
 Temporal bone, 17
 Tensor fasciae latae, 25, 27, 39, 35, 37
 Teres major, 31, 33
 Teres minor, 31
 Testes, 133
 Testicular
 artery, 107
 vein, 107
 Testis, 107, 109, 135
 Testosterone, 133, 135
 Thoracic, 69
 duct, 95
 nerves, 115
 region, 15
 vertebra, 29
 Thrombocyte, 93
 Thymus, 97, 135
 Thyrocervical trunk, 67, 75
 Thyroid cartilage, 45, 59
 Thyroid gland, 135
 Thyroid stimulating hormone (TSH), 133
 Thyroxin, 133
 Tibia, 15, 37
 Tibialis anterior (Tibialis cranialis), 35, 37
 Tissues, 1
 Tongue, 7, 49, 51, 53, 59
 Trachea, 45, 51, 53, 59, 61, 65
 Tracheal cartilage, 61
 Tracheobronchial, 95

Transverse plane, 3
Trapezius, 25
Triceps muscle, 29
Triceps, 25, 27, 31, 33
Tricuspid valve, 83
Trunk, 7, 27
Tympanic membrane, 125

U

Ulna, 15, 31
Umbilical, 67, 69
 arteries, 7, 73, 87, 89
 cord, 5, 7, 9, 45, 89, 107
 vein, 7, 45, 55, 73, 87, 89, 91
 vessels, 89
Ungulates, 5
Ureter, 89, 99, 101, 103
Urethra, 99, 101, 107
Urinary bladder, 89, 99, 101, 107
Urogenital
 opening/orifice, 9, 99, 101, 107
 papilla, 9, 101, 111
 sinus, 101, 111
Urogenital system
 female, 101
 male, 99
Uterine
 body, 111
 gland, 113
 horns, 111
Uterus, 101, 111

V

Vagina, 101, 111
Vagus nerve, 77
Vas deferens, 107
Vastus lateralis, 35
Vastus medialis, 27, 37
Vein, 67, 69, 71
Venous
 system, 69
 valve, 69
Ventral, 1, 3
 abdominal aorta, 87
 arteries, of digestive organs, 85
 heart, 79
 muscles, 27
Ventricle, 71, 73, 75, 79, 81, 83
Venule, 71
Vertebrae, 13
Vertebrae skeleton, 13
Vessels, head and neck, 75
Villus, 57
Visceral muscle, 21
Vitreous humor, 123

W-Z

White pulp, 97
Wrist, 7
Zygomatic bone, 17

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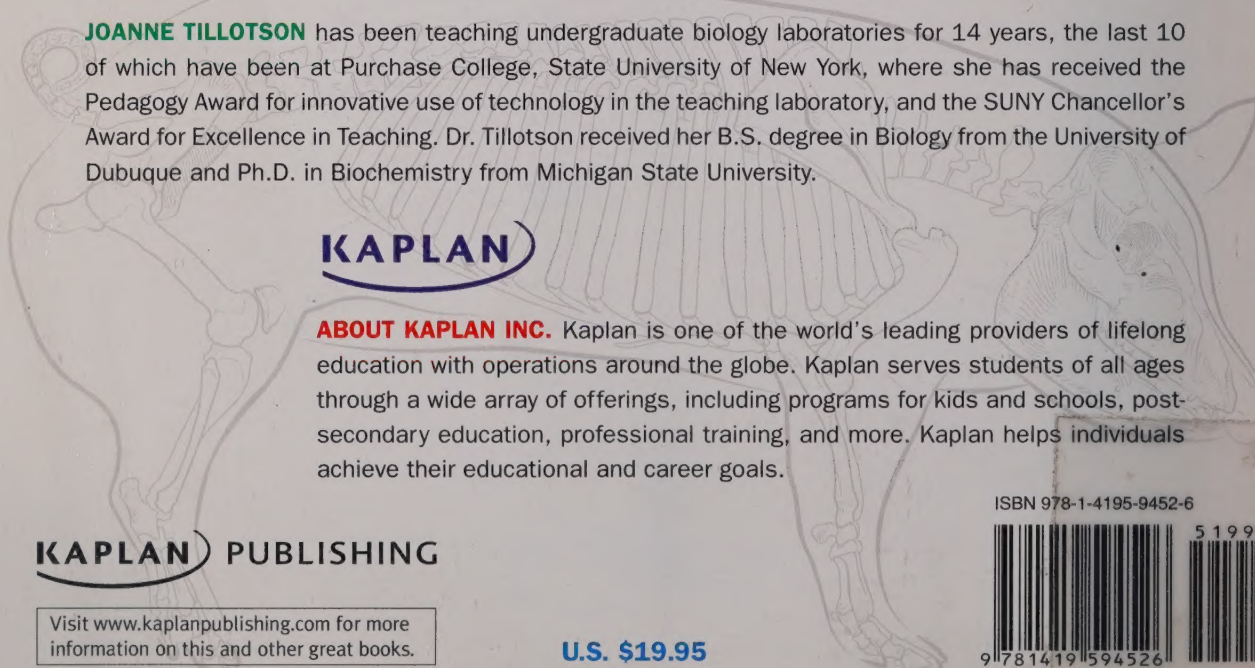
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